A SOIL SURVEY IN SALT LAKE VALLEY, UTAH.

By FRANK D. GARDNER and JOHN STEWART.

PHYSIOGRAPHY.

Beginning in July, 1899, four months were spent in a thorough and detailed study of that portion of the Salt Lake Valley lying west of the Jordan River, the object being to map the soils with reference to their character and to the extent of, and damage from, "alkali" and seepage waters. The soils were classified according to their texture, and the waters examined with reference to their quality for irrigation purposes. The soils were further studied with reference to their "alkali" content and its effect in varying amounts upon the crops and vegetation. The methods of irrigation were looked into with regard to their success or failure and the ultimate outcome in relation to the condition of the soils, especially with reference to the accumulation of alkali and seepage waters.

Nearly 700 borings were made in this district, usually to a depth of 6 feet and occasionally to 9, 12, or 15 feet. In two-thirds of these borings the per cent of salt at saturation in each foot section was determined by the electrical method, and in a considerable number of the borings the sodium carbonate (true black alkali) was determined volumetrically. In areas where hardpan forms an important feature, it was mapped and its depth and thickness ascertained. A study was made of its influence toward the action of roots and water together with the probable mode of formation.

Full notes were made on the character of the natural vegetation and the kinds and condition of the crops. Wells, both surface and artesian, were examined with reference to their water, the depth to standing water, and the nature of the strata through which they were dug. Drainage and seepage waters were tested with regard to the salts they were carrying from the soil.

Only such of the data collected as is essential for a clear understanding of the conditions is herein given, the results being embodied in the following text and accompanying maps.

Salt Lake Valley comprises about one-half of Salt Lake County, the remainder being occupied by the Wasatch Mountains to the east and

the Oquirrh Mountains to the west. The mountains close in on the south in what is known as the Jordan Narrows, thus practically surrounding the valley on three sides and leaving an opening on the north where it borders on the Great Salt Lake. It is one of many similar valleys which, lying between mountain ranges more or less parallel, go to make up the lower and more level parts of the Great Interior Basin, a broad area of varied surface naturally divided into a number of drainage districts.

The general form of the Great Interior Basin is triangular, with the acute angle to the south where it extends into old Mexico. At its greatest extremes it is 880 miles from north to south and 570 miles from east to west, including an area of 210,000 square miles. It comprises nearly the whole of Nevada, the western half of Utah, small portions of Idaho and Montana, and large areas in Oregon and in eastern and southern California.[1]

The region is characterized by many short and usually parallel mountain ranges, extending generally from north to south, between which are smooth valleys whose alluvial slopes or floors are built up of the débris brought down from the mountains. The character of the climate is plainly seen in the hydrography and vegetation. Perennial lakes occur only in association with the larger mountain masses, while the vegetation of the valley is usually sparse. The annual rainfall varies from 2 inches in the south to about 20 inches in the mountains in the north, while the annual evaporation from a free water surface varies from 60 inches in the north to 150 inches in the south. The larger mountains have timber in their recesses, but only conifers attain such size and abundance as to be of economic importance. The climate of the whole area may be classed as arid.

The largest subdivision of the Great Basin is the Bonneville Basin (fig. 6), containing 54,000 square miles, or a little more than one-fourth of the former. Slightly more than two-fifths of the Bonneville Basin was once occupied by the ancient Lake Bonneville, whose area was 19,750 square miles. This ancient lake apparently reached its greatest extent during the epoch of maximum glaciation, as is shown by the presence of a number of glacial morains which descend on the sides of the Wasatch Mountains to the well-marked shore line of the lake when at its highest stage. This shore line, known as the Bonneville shore line, forms a striking feature of the mountain side, both to the east and west, and is plainly visible from all points of the valley. (See Plate X.) The great upheavals which made the mountains and valleys of this region evidently occurred prior to the age of the lake, although there have been

---

[1] The following brief description of the characteristics and history of the Great Interior Basin and of Lake Bonneville is essential to an understanding of the present conditions. Some of the facts and figures relating to the basin and to the time and extent of the ancient lake have been taken from G. K. Gilbert's report on Lake Bonneville, published as a monograph by the United States Geological Survey in 1890.

minor changes in the elevation since then, as shown by faults at the western bases of the Wasatch, Oquirrh, and Aqui mountains and by the variations in the altitude of different parts of the Bonneville shore line. The altitude of this shore line has been ascertained in a number

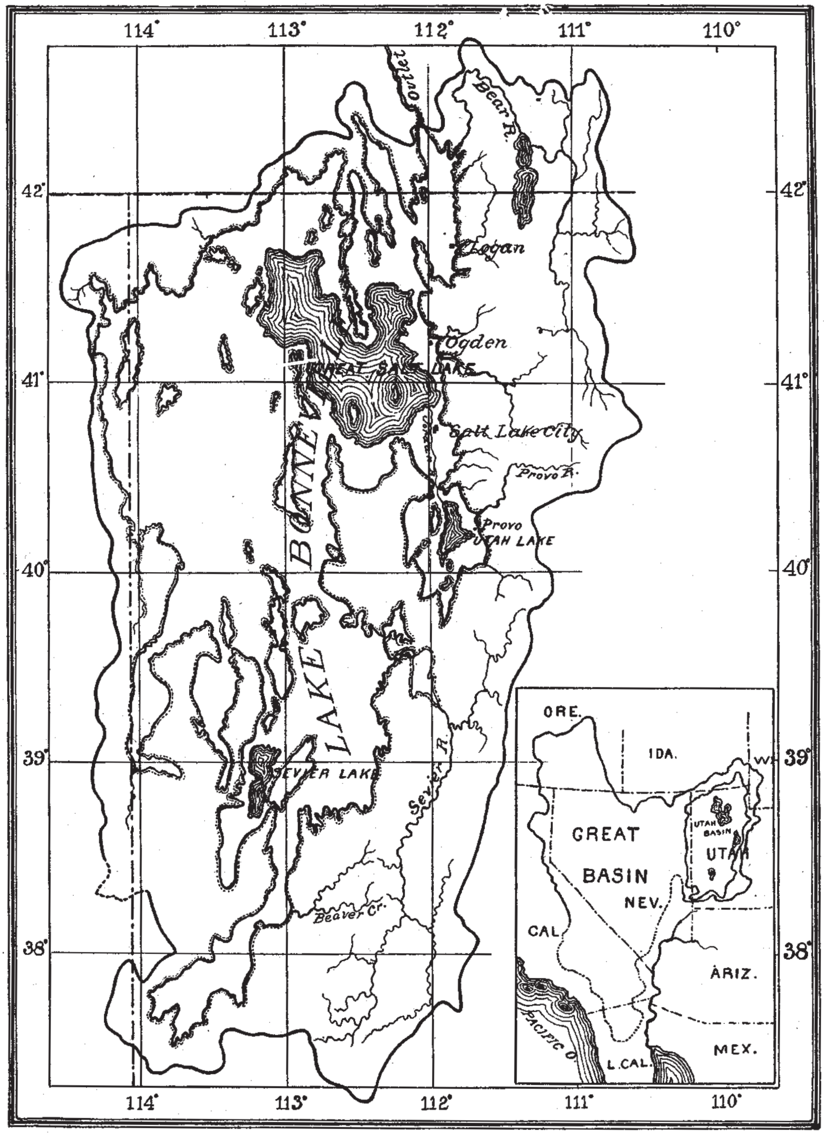


FIG. 6.—Sketch map of Bonneville Basin, showing ancient lake and present lakes.

of places, and, except in a few measurements at the extreme south, it varies from 900 to 1,070 feet above the present level of Great Salt Lake, with a mean elevation of about 1,000 feet. All evidences point to the fact that the surface of Lake Bonneville was at that time 1,000 feet

higher than the present surface of Great Salt Lake and that its areal extent exceeded the present lake by 13.3 times. At its highest stage the lake overflowed the rim of the basin, the water escaping into Snake River. A deep channel was eroded, forming what is now known as Red Rock Pass. The level of the lake was thus lowered 375 feet, at which point erosion ceased and no further escape of water occurred in this manner. Here the water level was maintained for a considerable period of time, as is shown by the formation of a well-marked beach line which is known as the Provo shore line. After this stage the lake water fell to its present level by evaporation, occasional interruptions being now noticeable by the number of intermediate shore lines more or less distinct. There is strong evidence of very great climatic change from epochs of great precipitation of snow and rain to periods when high temperature and excessive evaporation occurred. It is not at all improbable that the Great Salt Lake may have been dry at some period, although this question has never been settled.

The modern Great Salt Lake is but a remnant of its ancient predecessor, which at the time of its overflow may be considered as a fresh-water lake. Since the Provo stage, however, the water escaped only by evaporation through a long period of time during which the evaporation exceeded the precipitation, causing as a result a body of water containing in solution 22 per cent of salt. At the Provo stage the water surface of the ancient lake was 625 feet above the present level of the Great Salt Lake as determined by the altitude of the Provo shore line in a number of places. (See Plate X.) The mean depth of Great Salt Lake is now about 13 feet; therefore, the water over its present area at the Provo stage was forty-nine times its present depth. A comparison of its area at the two periods shows that at the Provo stage it was 7.4 times its present area. Assuming that the mean depth of the whole body of water at this early period was one half the mean depth of water at that time over the present lake, the volume of water at the former time is found to be one hundred and eighty-one times the present volume of Great Salt Lake. If it were further assumed that the lake at the Provo stage was fresh and contained, as the Utah Lake now does, about 80 parts of soluble matter in 100,000 parts of water, we would have, by evaporation to the present volume of Great Salt Lake, a solution containing 14.5 per cent of salt, providing none of the salt was precipitated during the process of evaporation. As a matter of fact the lake now carries about 22 per cent of salt, which leaves about 7½ per cent unaccounted for. We find, however, that the inflowing streams carry sufficient water to equal the volume of the lake water every 2½ years; and if it is assumed that they carry a percentage of salt equal to that carried by Utah Lake, it would require only two hundred and fifty years for them to carry the remaining 7½ per cent and bring the saltness of the lake to its present stage. No doubt considerable quantities of the less soluble salts—as, for example, carbonate of lime and sulphates of

NNEVILLE MARKS ON MOUNTAIN, 3 OR 4 MILES EAST OF GARFIELD BEACH.

neville shore line, and the lower well-defined one is the Provo shore line. The lake overflowed 375 feet en these levels, and has since evaporated 625 fect, down to its present level.

lime and soda—were deposited, but the period of time since the Provo stage has undoubtedly been much longer than two hundred and fifty years. It seems, therefore, quite simple to account for the present high salt content of the Great Salt Lake. At a time when the lake was just high enough to cover the lower levels of the Salt Lake Valley, the water must have been sufficiently salty to have left the soil in a very salty condition upon the subsidence of the water. As a matter of fact, large amounts of salt are found in the lower levels, especially in the lower depths of the soil.

Within the memory of the present inhabitants the level of this lake has varied fully 12 feet. In 1850 it was very low, but for several years thereafter it rose slowly. It then began to fall again, reaching a very low stage from 1861 to 1864. From 1864 to 1868 there was a period of excessive rainfall, during which time the lake rose rapidly, reaching such a height in 1868 that fully 50 square miles of what was mapped

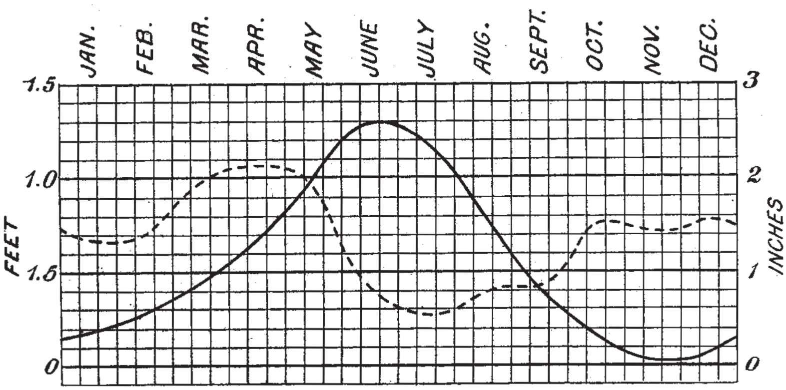


FIG. 7.—Diagram showing mean monthly fluctuations in water level of Great Salt Lake and the rainfall during same period. (The solid line represents level of lake; the broken line the rainfall.)

this season as dry land was submerged by its waters. Since that time there have been three distinct periods of rise and fall, but the general trend has been downward, until at the present time the level is about where it was in 1850. Besides this, there is an annual fluctuation, during which the lake reaches its maximum about June 1 and its minimum about December 1. This annual variation, amounting to from 1 to 2 feet, is the result of a low rainfall from June to September, inclusive, accompanied by high temperature and low relative humidity, conditions favoring rapid evaporation and of a greater rainfall and less evaporation during the remainder of the year. This is shown in figure 7.

The accompanying diagram (fig. 7) shows graphically the mean monthly rainfall in inches as compared with the monthly change in the level of the lake in feet. The maximum rise of the lake occurs about two months after the close of the rainy period, and it is about the same length of time after the rain again begins before the lake commences

to rise, which shows that the maximum effect of precipitation on the lake occurs about two months after the precipitation has taken place. Figure 8 shows the semiannual variation in the lake level for the past fifty years, with the accompanying annual rainfall. There is a general agreement between precipitation and the lake variation.

The surface of Great Salt Lake is 4,170 feet above the sea level, while an additional 50-foot contour line would include the lower and more level portions of the valley, amounting to one-half of it. Above this the land inclines toward the foothills at the rate of from 50 to 100 feet per mile. To the east the Wasatch Mountains rise abruptly, attaining a maximum height of 7,000 feet above the general level of the valley. Their snow-clad summits and numerous springs are the source of a number of perennial streams that flow across the eastern part of the valley and enter the Jordan River. These streams furnish an

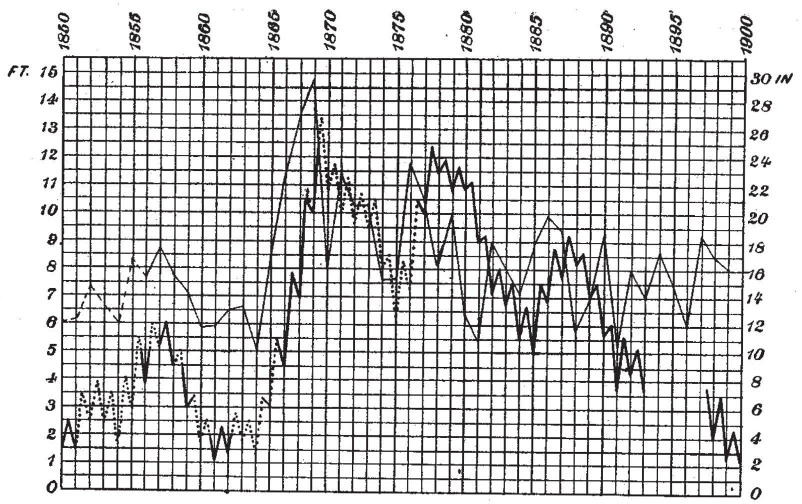


FIG. 8.—Diagram showing mean annual fluctuations in water level in Great Salt Lake and the rainfall during the same period. (The heavy line represents the level of the lake in reference to an established bench mark; the light line represents the rainfall in inches.)

abundant and good water supply for irrigating the eastern portion of the valley. To the west the Oquirrh Mountains rise less abruptly, reaching an elevation of from 4,000 to 5,000 feet above the valley. The watershed is not so extensive as to the east, and there is less snow, so that the few streams flowing from the canyons are lost, by evaporation or seepage, before they reach the Jordan River. The Jordan River is the main channel through which the waters of Utah Lake and its inflowing streams reach Salt Lake. It is on the Jordan River that the western portion of the valley is dependent for irrigation water.

The mountains consist chiefly of granite, limestone, sandstone, quartz, porphyry, and feldspar, and it is from these rocks that the soil of the valley is formed. The mountains abound in ores rich in silver, lead, and copper. Many mines are in operation and furnish material for several large smelters located in the valley.

The lake is also a source of commercial enterprise, and according to the statistics of 1890 the value of the annual output of the salt harvested from the evaporating ponds amounted to $250,000.

CLIMATE.

The climate of Salt Lake Valley is characterized by low annual precipitation, low relative humidity, moderate wind movement, moderate temperature, and abundant sunshine. It may be classed as arid. According to the United States Weather Bureau records for the past 25 years, the mean annual precipitation at Salt Lake City is 16.2 inches, with a minimum of 10.3 inches in 1890 and a maximum of 23.6 inches in 1875. Previous records, shown in the chart on page 82, show a range in annual precipitation of from 10 to 29 inches. Of the mean annual rainfall a total of only 2.9 inches falls during the months of June, July, August, and September. These four months of mean minimum precipitation are accompanied by mean maximum temperature and low relative humidity—conditions favoring excessive evaporation.

Since this is the period in which crops make most of their vegetative growth, it will be seen how important and necessary is irrigation water for farming. In fact very little farming is carried on except under irrigation. Statistics for 1894 show that 92.5 per cent of the farms in Salt Lake County are irrigated. Wheat is the only crop that is grown without irrigating and it makes most of its vegetative growth prior to June. The average yield of wheat under dry farming is slightly more than one-third of the average yield under irrigation.

The accompanying table shows the monthly and yearly precipitation at Salt Lake City for the past 25 years as obtained from the United States Weather Bureau office at that place.

Monthly and annual precipitation, Salt Lake City, Utah, from 1874 to 1899.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1874	......	......	*a*1.31	0.90	2.84	0.74	2.42	1.63	0.20	1.74	2.16	0.73	14.67
1875	3.05	0.79	2.81	1.50	2.91	.90	1.01	.25	1.22	1.36	5.81	2.03	23.64
1876	1.23	1.52	4	2.09	4.30	.09	.83	.92	.42	3.27	.81	1.80	21.28
1877	.87	.38	2.93	2.14	3.49	.80	.02	.28	.90	2.41	1.02	1.11	16.35
1878	1.07	3.49	2.54	2.63	2.50	.35	1.08	.81	3.15	1.39	.63	.11	19.75
1879	1.87	.71	.67	3.26	.10	1.34	.07	.06	.01	1.62	.32	3.08	13.11
1880	.29	1.02	.43	2.37	1.85	.01	.20	.74	.56	.40	1.17	1.90	10.94
1881	1.24	2.44	.88	2.37	2.55	.28	.21	1.66	.43	2.19	1.44	1.24	16.93
1882	1.50	.42	1.12	3.81	.26	2.24	.30	1.61	.37	2.89	.54	.92	15.98
1883	1.47	.72	1.75	2.92	.98	.33	.10	.62	.13	2.24	1.78	1.20	14.24
1884	.71	2.23	3.69	2.89	1.78	.33	.27	.73	1.91	.36	.50	2.12	17.52
1885	1.48	1.56	.64	*b*3.47	2.49	2.67	.58	.90	1.29	.59	3.10	.92	19.69
1886	1.91	1.36	2.60	4.43	.06	1.02	T.	.59	1.88	1.98	1.79	1.27	18.89
1887	2.36	1.41	.35	1.87	.73	.37	1.23	.69	.55	.30	.25	1.55	11.66
1888	1.52	1.22	2.18	.99	.34	.98	.24	.63	.51	.80	2	2.21	13.62
1889	.73	.81	1.64	1.52	2.97	.01	.08	.92	.52	3.85	1.04	4.37	18.46
1890	3.07	2.05	1.12	.94	.16	.32	.02	.79	T.	1.44	T.	.42	10.33
1891	.74	.76	4.66	1.49	.72	1.08	.47	.46	1.19	1.26	.90	2.19	15.92
1892	1.61	.68	2.21	1.90	1.65	1.21	T.	.05	.12	1.58	.72	2.35	14.08
1893	.82	1.64	2.68	2.72	1.68	.04	1.19	.71	1.30	1.02	1.18	2.37	17.35
1894	1.31	.83	1.73	1.67	1.22	1.38	.82	.87	2.87	1.01	.28	1.28	15.27
1895	1.32	.85	.81	.73	2.29	.99	.42	.02	.95	.24	2.44	.89	11.95
1896	1.26	.69	1.99	2.53	3.67	.25	1.35	1.47	.52	.70	3.15	.84	18.42
1897	1.16	3.81	2.20	2	.98	.52	.69	.33	.48	1.91	1.19	1.47	16.74
1898	.58	.38	1.71	1.30	4.19	1.45	.18	1.35	.15	1.57	1.95	1.28	16.09
1899	.84	2.98	2.93	.81	2.59	.96	.42	1.06	T.	......	......	......	12.59
Sums	34.01	34.75	51.58	55.25	49.30	20.66	14.20	20.15	21.63	38.12	36.17	39.65	402.88
Averages	1.36	1.39	1.98	2.12	1.90	.79	.55	.78	.83	1.52	1.45	1.59	16.18

a 12 days. *b* 28 days.

The annual precipitation in the mountains is greater than in the valleys, and it is estimated that it includes 6 feet of snow, which lingers on the mountains the greater part of the summer. This is important in relation to irrigation, because it makes the water supply plentiful throughout the season.

The annual evaporation from a free water surface in Salt Lake Valley is estimated at 8 feet. Data from one of the salt companies show the evaporation from their ponds to be about 37 inches from June to September, inclusive. It should be borne in mind, however, that this is from a saturated salt solution and that the presence of much salt lowers the vapor tension, and, consequently, the rate of evaporation. The evaporation from a fresh-water service would no doubt have been much greater.

The mean annual temperature is 51.2° F., with a mean maximum of 75.6° in July and a minimum of 27.9° in January. The mean temperature for from June to September, inclusive, is 70.5° F.

The following table gives the mean monthly and yearly temperature for the past twenty-five years.

Mean monthly and mean annual temperature, Salt Lake City, Utah, from 1874 to 1899.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1874	......	......	......	......	......	67.1	77.8	74.6	62	56.4	43.2	33.9	......
1875	29.5	34.2	35	48.9	59	67.8	74	75	68.1	58.2	42	36.2	52.4
1876	30.5	36.1	37.2	49.8	56.7	68.6	76.5	71.6	65.8	55.3	41	27	51.2
1877	27.2	34.1	46.9	48.8	56.2	65.4	77.4	75.8	64.4	51.6	40.6	32.1	51.4
1878	30.3	37.8	47.1	49.4	56.4	68.5	76.9	78.4	60.6	49	44	29.8	51.9
1879	28.3	39.6	49.2	52.6	58.2	65.2	76.8	75.4	68.5	52	36	29.4	53
1880	28.2	26.2	34	46.8	54.2	66	74.2	72.8	63.6	52	29.6	34.6	48.6
1881	30.8	38.2	42.2	54.2	60.2	71.2	76	74.4	60.2	50.8	33.8	33.6	51.8
1882	23.5	26.9	36.6	46.7	57.2	67.3	75.4	76.9	64.8	48.4	35.5	35	49.2
1883	24.4	24.1	47	45.6	56.7	70	76.2	76.8	69.7	46.3	39.2	32.5	50.8
1884	28.4	30.7	40.8	48	57.9	69.1	74	72.7	59.4	53	42.2	35.2	51.4
1885	27.6	36.8	45.6	53.5	56.6	64.8	76.1	73.7	65.1	54.9	43.8	33.9	52.3
1886	28.8	40.8	37.7	48.4	62.4	68.9	78.1	76.1	62.8	51.8	31.4	36.1	51.6
1887	33.2	34.1	47.2	49.2	60.8	68.6	74.9	73.4	65.5	51.6	42.8	29.2	52.7
1888	22.9	38.3	40	54.8	58.6	68.4	76.6	74.8	70.6	54	41.6	35.8	53
1889	21.4	29.8	47.7	55.2	58.8	70.3	78.4	77.4	60.6	54.2	39	39.6	52.7
1890	24.8	33.7	39.5	50.4	61.3	64.8	77.8	72.9	65	48.6	41	36.2	51.6
1891	28.8	30.6	38	49.6	60	62	73.3	74.4	65	53.2	44.2	28.6	50.6
1892	25.8	33.6	43.4	47.4	55.4	65.8	76	75.4	69.6	51.8	42.2	27.6	51.2
1893	27.6	28.5	39.3	45.9	55.1	67	74.7	73.3	63	52	39.4	36.3	50.2
1894	29	25.6	41.1	48.1	61.2	63.9	74.6	75.4	61	53.2	45.6	31.4	50.8
1895	29.7	30	40.8	51.2	57.9	63.5	72.6	74.8	63.8	54.3	37.8	26.4	50.2
1896	34	36.8	40.2	46.4	51.4	70	74.2	73.7	64	54.4	37.2	36.2	51.5
1897	28.8	30.9	33.6	49	63.4	66	71.9	75.2	62.2	50.9	43.2	27.4	50.2
1898	20.6	35.6	36.3	54	53.9	67.1	75.9	76.8	65.6	48.2	37.3	25.2	49.7
1899	33.8	29.6	40.6	50.6	52.6	65.1	76.2	69.8	67.1	......	......	......	......
Average	27.9	32.9	41.1	49.8	57.7	67	75.6	74.7	64.5	52.2	39.7	32.4	51.2

The mean annual wind movement is at the rate of 5.4 miles per hour, with a maximum of 6.4 miles in May and a minimum of 4.3 miles in November.

The following table gives the monthly and annual wind movement at Salt Lake City for the past twenty-five years. As a whole, the climate is both pleasant and healthful.

Monthly and annual wind movement in miles at Salt Lake City, Utah, from 1874 to 1899.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1874	......	......	....	4, 227	4, 116	4, 231	3, 421	3, 924	3, 240	2, 681	3, 076	2, 272	*a* 31, 188
1875	3, 395	2, 701	4, 492	4, 394	4, 672	4, 407	3, 923	4, 406	3, 983	3, 087	3, 262	2, 031	44, 753
1876	2, 915	2, 460	4, 169	3, 689	3, 537	3, 570	4, 252	4, 910	4, 524	3, 418	2, 887	1, 636	41, 967
1877	3, 222	2, 411	4, 219	5, 206	6, 291	4, 531	5, 165	4, 848	4, 783	3, 998	3, 777	2, 978	51, 429
1878	2, 569	3, 568	4, 150	5. 057	5, 229	4, 970	5, 535	4, 083	3, 830	4, 406	3, 148	2, 895	49, 440
1879	2, 898	3, 336	5, 001	4, 739	6, 410	5, 085	4, 503	4, 783	4, 104	3, 694	2, 222	3, 605	50, 380
1880	3, 516	3, 292	5, 003	5, 693	5, 475	4, 534	4, 090	3, 878	3, 601	3, 499	2, 090	3, 801	48, 572
1881	3, 360	2, 072	4, 045	3, 174	3, 773	3, 759	4, 394	4, 199	3, 916	4, 000	2, 205	1, 473	40, 370
1882	2, 100	2, 952	3, 810	5, 009	5, 569	4, 713	4, 321	4, 476	3, 779	3, 895	2, 613	2, 726	45, 963
1883	2, 333	2, 590	4, 136	4, 914	3, 350	4, 168	3, 224	3, 312	3, 793	3, 746	3, 166	2, 984	41, 716
1884	3, 257	4, 075	4, 662	4, 443	4, 613	4, 875	4, 023	3, 492	3, 844	3, 947	2, 422	5, 410	49, 063
1885	2, 410	2, 378	2, 770	3, 006	2, 652	3, 853	4, 366	3, 921	3, 584	2, 823	3, 705	2, 808	38, 276
1886	3, 520	2, 822	3, 736	4, 319	4, 534	4, 146	4, 287	3, 210	3, 734	4, 193	2, 730	2, 239	43, 470
1887	3, 862	5, 350	3, 933	4, 877	4, 926	4, 589	3, 800	4, 524	3, 723	3, 414	2, 863	3, 406	49, 267
1888	3, 776	3, 201	4, 736	4, 160	4, 562	4, 989	4, 123	4, 333	2, 947	3, 619	2, 648	2, 441	45, 535
1889	2, 256	2, 229	4, 180	4, 758	4, 920	4, 402	4, 808	4, 309	3, 567	3, 430	2, 857	4, 539	46, 255
1890	4, 095	3, 920	4, 232	4, 196	4, 272	4, 507	3, 602	3, 279	2, 806	2, 745	2, 008	2, 201	41, 863
1891	2, 217	4, 320	3, 300	3, 761	4, 205	4, 135	3, 618	4, 041	4, 860	3, 798	3, 261	4, 368	45, 884
1892	2, 474	2, 234	4, 935	3, 954	3, 952	4, 501	5, 039	4, 355	4, 313	3, 778	5, 377	3, 612	48, 524
1893	3, 695	3, 822	4, 810	5, 741	5, 729	5, 173	4, 532	4, 196	4, 973	3, 876	3, 775	3, 256	53, 578
1894	4, 135	4, 305	5, 273	4, 958	5, 387	4, 836	4, 167	4, 358	4, 401	4, 366	3, 187	4, 132	53, 505
1895	4, 571	2, 947	5 886	5, 638	5, 513	4, 559	4, 464	4, 134	5, 140	3, 966	3, 512	3, 804	54, 134
1896	4, 274	3, 601	4, 382	5, 710	4, 963	4, 460	4, 108	4, 185	5, 002	4, 234	4, 166	3, 239	52, 324
1897	2, 662	3, 742	5, 490	5, 215	5, 020	4, 663	4, 687	4, 238	4, 637	4, 376	3, 557	3, 436	51, 723
1898	3, 169	3, 460	5, 148	5, 018	4, 539	4, 733	4, 334	4, 486	4, 432	3, 878	3, 679	3, 799	50, 675
1899	4, 449	3, 343	5, 044	5, 356	5, 058	4, 664	4, 348	4, 913	3, 748	......	......	......	*a* 40. 923
	81, 130	81, 231	111, 542	121, 212	123, 267	117, 053	111, 134	108, 793	105, 264	92, 867	78, 193	79, 091	1, 210, 777
Average	3, 245	3, 250	4, 462	4, 662	4, 741	4, 502	4, 274	4, 184	4, 049	3, 715	3, 128	3, 164	*b* 47, 444

a For 9 months. *b* For 24 years.

HISTORY OF IRRIGATION.

Modern irrigation in the United States began in Salt Lake Valley, Utah, when the Mormons settled there in 1847. One of the first undertakings after reaching the valley was the diverting of the water of what is now known as City Creek and the irrigation of a few acres of land planted with seed brought with them on their long and perilous journey from Illinois.

Traces of irrigation antedating the Salt Lake Valley undertaking are to be found in Arizona in the systems (long since abandoned) of an extinct race of aborigines, and in southern California, where irrigation was practiced by the mission priests.

An historian of the Mormon Church describes the present site of Salt Lake City as follows:

> A desolation of centuries, where earth seemed heaven forsaken, where hermit nature—watching, waiting—wept and worshipped God amid eternal solitude.

Charles Brough, in his Historical and Political Studies on Irrigation in Utah, says:

> The transformation of this sterile waste, glistening with beds of salt, and soda, and deadly alkali, seemed impossible.

These quotations give an idea of how the conditions appeared to the first settlers. In the year 1848, 5,153 acres were put under irrigation,

and the amount of land under irrigation in this locality has since rapidly increased. The growth of Salt Lake City was very rapid, and in 1850 the population numbered 11,354. During this year there were over 16,000 acres under cultivation. In 1852 the assessed value of property was $400 per capita. To-day the city possesses a population of 70,000. The broad streets are lined with rows of stately trees and the comfortable homes are surrounded by luxuriant lawns.

The rural districts are populous; the farms are small and are characterized by an intensive and diversified form of agriculture. In the whole State of Utah the average size of the irrigation farms is 27 acres.

According to statistics gathered in 1894 by the State statistician, there were 2,195 farms in Salt Lake County, 90 per cent of which were cultivated by the owners. Of the total number of farms only 14 per cent were incumbered by mortgage.

Notwithstanding the success that has been attained, serious damage has occurred in places through the accumulation of seepage waters and alkali. Districts once successfully farmed have been abandoned and the attempts at reclamation have failed, because suitable methods have been wanting. Damaged lands are more apparent now than formerly, and demand for methods of preventing such damage and for reclaiming waste land is greater than ever before.

The earliest irrigation was principally on the east side of the Jordan River, the irrigation waters being obtained from the numerous small streams issuing from the canyons of the Wasatch Mountains. The canals, always small, were constructed by cooperative labor, cooperation being the watchword of the Mormons and even to the present time predominating in all lines of mercantile pursuits.

A number of farmers owning land along a stream joined together and by their collective labor constructed a canal that brought water to all of their farms. The distribution of the water was proportional to the amount of land owned by each. The advantage of this method was that it gave water to each farmer without expenditure of money and without waiting. The canals were crudely constructed and no provision was made against leakage. Water was turned into the canals in the spring and not turned out until fall, in some instances even running throughout the year. As a result the large amount of waste and seepage waters did much damage to lands lying below the neighborhood irrigated, and at the present time a large area of land immediately south of Salt Lake City and adjacent to the river is much affected by seepage waters and alkali.

On the west side of the Jordan River the earliest attempts at irrigation were on the Jordan meadows or river bottom lands, the water supply being obtained from the Jordan River by means of small canals. Subsequently the Brighton and North Point and the North Jordan canals were run upon the first terrace above the river, and following these were the South Jordan and the Utah and Salt Lake canals on the second and third benches, respectively.

As is frequently the case, the irrigation on the benches caused an accumulation of seepage and alkali on the river bottom land, so that much of it has been abandoned. The largest and most seriously damaged area, however, is just south of Twelfth Street road, and comprises a strip of land varying from half a mile to a mile and a half in width, and extending 10 miles west from the river. Here the seepage and surplus waters from the outer extremities of the Utah and Salt Lake, the South Jordan, and the North Jordan canals have collected to an alarming extent. Indeed, the damage has gone so far that a chain of lakes has formed, presenting a water surface of fully 1,000 acres. The area affected is not less than 10 square miles.

That portion of Salt Lake Valley west of the Jordan River which is at present under irrigation includes about 40 square miles, and covers a strip about 2 miles wide, bordering on the river and extending through Ts. 2 and 3 S., R. 1 W., together with another narrower portion at the north, which bends to the west through T. 1 S., Rs. 1 and 2 W., nearly to the point of the mountains. It consists mainly of terraces, one above another, and has a slope toward the river or to the north of 50 to 100 feet per mile.

In addition to the above-named canals there is the surplus canal, from which the North Point Consolidated Canal is taken. The latter conducts water to the low-level area north of the base line, but is little used for irrigating purposes because of the unsatisfactory results of applying water to this level, salty land.

The irrigation canals on this side of the river have an aggregate capacity of about 600 cubic feet per second, but less than half of this amount is required or used on the 25,000 acres under cultivation. On the low-level area, between Salt Lake City and the lake, many attempts have been made and much money expended in the endeavor to successfully irrigate the land; but, with a few minor exceptions, the attempts have all proved failures.

The canals are owned, for the most part, by the owners of the land under irrigation, and the only paid officer is the "water master," whose duty it is to attend to the equitable distribution of the water to the shareholders. At stated intervals, along the main canals, laterals are taken out to supply the farms along its course. Each lateral has a head gate, the opening or closing of which is controlled by the water master, and the size of the opening is varied according to the number of shares supplied by the lateral and the total water supply for the canal. If the water supply is plentiful, the gates usually remain with a certain-sized opening throughout the season, and the water is permitted to flow continuously. Each shareholder is entitled to use all of the water flowing in the lateral for a stated number of hours and at stated intervals, according to a schedule agreed upon at the beginning of the season.

SOILS.

The area surveyed in 1899 includes all of that part of Salt Lake Valley lying west of the Jordan River, and is equal to about two-thirds of the entire valley. It extends westward to the foothills of the Oquirrh Mountains and the Great Salt Lake and northward to the lake. The area, roughly estimated, is 14 miles east and west by 28 miles north and south at its greatest extremes, and includes over 250 square miles.

Topographically the area varies in elevation from the present level of the lake, which is 4,170 feet above sea level, to about 4,700 feet at the foothills. A contour taken 50 feet above the lake would include the northern half of the district, which is comparatively level. The portion above such a contour inclines toward the mountains at the rate of from 50 to 100 feet per mile. The drainage is into the Jordan River or directly into the lake.

The soils have been formed by material brought down from the mountain sides and by sediments from the ancient Lake Bonneville, all of which have been materially modified by inflowing streams from the mountains and by the vacillating shore of the lake. Soils formed in this way are usually heterogeneous, and these soils form no exception to the rule. In the lower part of the valley the sediment is very deep, no rock or gravel being found at a depth of a hundred or more feet. As we get near the foothills, gravel and rock are plentiful and often crop out at the surface. Here there is little or no lake sediment apparent.

The soils are fertile, but in the natural condition support only a meager vegetation, because they are either too dry or too salty. On the higher portions, where there is little salt present, sagebrush forms the chief growth, while in the lower areas, where there is more moisture and much salt, salt-loving perennials, such a greasewood and "mutton sas," abound.

The following classification of the soils is based on the judgment of the field experts, typical samples of the various types being sent to the laboratory and analyzed, not as a basis for classification, but in order to obtain an explanation of certain characteristics as they appeared in the field.

The chief basis of the classification is texture, as determined by the feeling and appearance of the soil, and it will be seen by studying the analyses of samples of the different types that the judgment of the experts is quite as accurate as the analysis itself.

The classification is based chiefly on the characteristics of the first foot in depth of the soil, although the underlying stratum is sometimes considered, as in the case of the Bingham gravelly loam, where the gravel is sometimes absent in the top foot, but occurs in the second or third foot.

The soils have been classified under eight types, in the order of the magnitude of their respective areas, as follows:

1. Jordan sandy loam.
2. Bingham gravelly loam.
3. Jordan loam.
4. Jordan clay and clay loam.
5. Jordan meadows.
6. Jordan sand.
7. Bingham stony loam.
8. Salt Lake sand.

JORDAN SANDY LOAM.

This loam, shown on the soil map by the orange color, comprises about 30 per cent of the entire district, and is the most important of the various types of the soil, both in extent and quality. It is a light, sandy loam, varying from one to several feet in depth, the texture of which is shown in the accompanying table of mechanical analyses.

Mechanical analyses.

No.	Locality.	Description.	Salt as determined in mechanical analysis.	Moisture in air-dry sample.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to .1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.01 mm.	Fine silt, 0.01 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
	Jordan sandy loams 0 to 12 inches in depth.		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
4303	SW. ¼ sec. 17, T. 1 N., R. 1 W.	Dry level land..	0.49	1.18	1.84	0.16	4.17	11.40	27.87	17.76	23.49	2.64	8.79
4311	SE. ¼ sec. 31, T. 2 N., R. 1 W.	Low level land.	.41	.94	2.17	1.10	3.28	7.80	15.23	23.46	33.06	2.80	9.47
4309	C. sec. 24, T. 1 S., R. 2 W.	Dry level land..	1.69	1.62	9.20	0.00	.12	.61	26.87	23.55	23.30	3.59	10.87
4369	S. C. sec. 17, T. 1 S., R. 1 W.	.....do..........	1.50	1.45	3.31	T.	.28	.95	8.84	39.31	29.44	3.28	11.74
4310	C. sec. 20, T. 1 N., R. 2 W.	.....do..........	1.09	1.79	5.25	.13	3.96	9.61	20.13	16.43	26.36	2.59	13.37
4297	N. C. sec. 27, T. 1 N., R. 2 W.	.....do..........	.89	1.55	4.57	.18	3.42	10.01	23.74	15.65	24.38	2.80	13.55
4365	NE. C. sec. 16, T. 2 S., R. 1 W.	Alfalfa, irrigated.	.30	1.95	5.42	T.	.77	4.98	3.11	26.82	35.85	3.87	14.58
4366	S. C. sec. 1, T. 1 S., R. 2 W.	Trees, irrigated.	.44	1.27	4.05	.67	1.06	1.43	9.11	29.85	33.08	4.75	15.03
	Subsoils under Jordan sandy loams.												
4370	Loam 24 to 36 inches.	Under 4369.....	1.08	1.49	5.61	T.	.48	1.63	8.61	27.12	29.42	2.60	22.43
4371	Sandy loam 36 to 60 inches.	.....do..........	.66	.99	4.24	.....	T.	.82	5.90	42.41	30.33	2.79	13.10
4367	Loam 12 to 24 inches.	Under 4366.....	.44	1.27	5.16	.35	1.11	1.40	5.84	30.05	31.11	5	18.21
4368	Fine sand=sandy loam 24 to 48 inches.	.....do..........	.46	.90	3.94	T.	.31	.34	3.10	46.38	32.82	2.72	9.54

The analyses of the eight samples of soil in the above table, the samples being taken from the first foot in depth, probably represent the range in texture for this type of soil. The clay content is comparatively low, ranging from a minimum of 8.79 per cent to a maximum of 15.03 per cent with a mean of about 12.2 per cent, which may be taken as representing the average clay content of this type of soil. By far the larger part of the separations occur under the heads of very

fine sand and silt, which give an average of 24.1 and 28.6 per cent, respectively.

The soil varies somewhat in underlying strata, but the most usual profile is 2 feet of sandy loam, 1½ feet of loam, and 1 foot of fine sand, underlaid by clay to considerable depth. In the above table Nos. 4370 and 4371 show the texture of the loam and sandy loam (the latter approximating very fine sand) which underlie soil No. 4369, while Nos. 4367 and 4368 represent the loam and fine sand underlying soil No. 4366. The clay, which usually occurs at a greater depth than these samples represent, corresponds in texture to the analyses given for the same under Jordan loam on page 95. Subsoils of this texture permit a ready movement of the ground water, and should therefore be easily underdrained by placing lines of tiles 150 feet apart.

As a rule the Jordan sandy loam overlies the Jordan loam, on which it generally borders, and it occurs mostly in the irrigated district and the low land to the north. That portion of it lying above the irrigation canals, as well as that in the irrigated district wherever the water table is 10 or more feet below the surface, is free from any excessive amount of salts. On the low area to the north, however, it generally contains considerable salt, especially in the lower depths. The native vegetation on this part of it consists mainly of greasewood and shad scale (perennial bushes growing from 1 to 4 feet in height) on the drier and less salty portions; and of mutton sas, salt grass, and various small salt-loving annuals on the moist and more salty places.

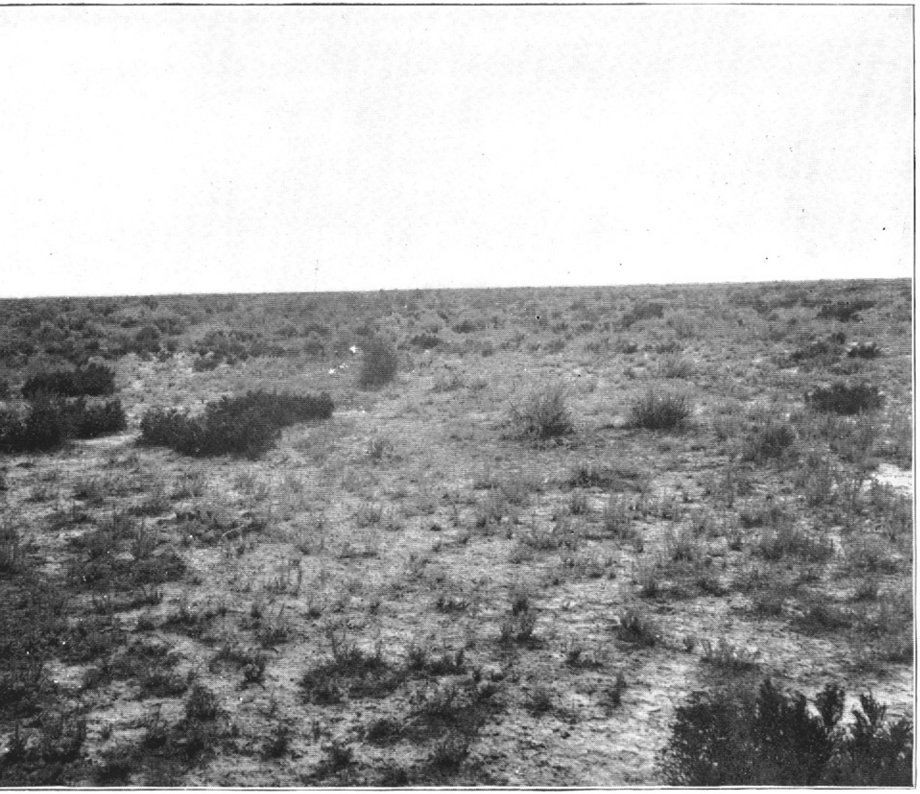
The accompanying table shows the per cent of salt in solution when the soil is saturated with water for various depths and places in the Jordan sandy loam, the percentage being calculated on the water-free soil.

Table showing the soluble salt content at saturation for various places and depths in Jordan sandy loam.

Number of boring.	Depth, in feet.									Depth to standing water.
	1.	2.	3.	4.	5.	6.	7.	8.	9.	
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Feet.*
200	0.06	0.05	0.05	0.06	0.08	0.08	0.10	0.11	0.11	10+
206	.06	.05	.06	.05	.09	.15				20
16	1.51	1.17	.74	.50	.62	.72				4
99	.76	.63	.40	.35	.29	.28				3½
300 *a*	.18	.15	.19	.25	.25	.20				4
651	.35		1.02		1.06					4
629	.11	.54	.88	*b*.33	*b*.35	1.64				6+
644	.14	.68	1.01	1.12	1.39	2.00				6+
517	.40		.76		1.04					7
626	.09	.48	.85	1.10	1.54	2.22				6+

a Irrigated. *b* Sand pocket.

Borings Nos. 200 and 206 represent about the mean salt content of this type of soil on the good irrigated land. Here the salt rarely exceeds 0.1 per cent above a depth of 5 feet. While there is a gradual increase in the salt as we go down, it never occurs to an alarming



VEGETATION OF GREASEWOOD AND SALTBUSHES ON JORDAN SANDY LOAM.

This land in its natural state is adapted only to the grazing of sheep.

extent, although there may be sufficient to wash out into seepage areas below, and thus cause damage by its accumulation.

Borings Nos. 16, 99, and 651 show the condition on the low land where the water table is within 4 or less feet of the surface. Here there is a comparatively large amount of salt present and Nos. 16 and 99 show an accumulation in the surface foot, which is usually the case when the water is 3 feet or less below the surface. These borings were made during the driest part of the year, and it is probable that the water table is nearer the surface during the time of the year when more rain falls.

Boring No. 300 is in a favorable location on the low land where the water, before irrigation was undertaken, was nearly 10 feet below the surface. It has been irrigated for three years and is now planted in trees. The salt content is fairly uniform in its distribution and, while not present in great quantity, there is sufficient to cause serious trouble if allowed to accumulate in the surface portion of the soil. This it is likely to do if the water table rises much above its present level.

Borings No. 629, 644, 517, and 626 are representative of the amount and vertical distribution of the salts for the unirrigated low-land part of this type of soil, where the depth to standing water is 6 or more feet, which is usually the case. In these samples the aggregate amount of salt to the depth of 6 feet is considerable and will correspond to the area shown on the map by an appropriate color, where the salt content to a depth of 5 feet ranges from 0.6 to 1 per cent. A small portion of this type of soil, however, falls within another area on the map, where the salt content exceeds 1 per cent, while, on the other hand, some of it falls in the blue area, with less than 0.6 of 1 per cent. The first foot usually carries a relatively small amount of salt and indicates that crops could be successfully grown. As we go deeper, however, the amount of salts increases very rapidly and the second foot is usually about the limit for alfalfa, while the third foot almost invariably contains too much to permit the growth of any agricultural crops. At 6 feet there is usually about 2 per cent of salt.

This distribution of the salts probably occurs because the rains wash them downward more rapidly than they are returned toward the surface by evaporation. If irrigation water were applied, the salts would continue to move downward, provided the water table remained at its present depth. Unfortunately, however, the application of water invariably causes a rise of the water table, and if the application be continued over a considerable area the water table comes sufficiently near the surface to cause excessive surface evaporation, which results in an upward movement of the salts and their consequent accumulation at the surface. The present surface conditions as regards the amount of salt are fairly good over considerable areas, but in order to improve or even maintain these conditions under irrigation thorough underdrainage is imperative.

The Jordan sandy loam is easily cultivated and is sufficiently fertile to produce almost any class of crops. It forms the most valuable portion of the low salty area, because of the ease with which it may be reclaimed by underdrainage and washing. Owing to the light texture of the subsoil, the lines of drains could be farther apart than in the heavier soils, and it would therefore be less expensive to drain.

The diagram on page 93 (fig. 9) shows sections in various directions in the valley and illustrates the constitution of the soils to a depth of 6 feet.

BINGHAM GRAVELLY LOAM.

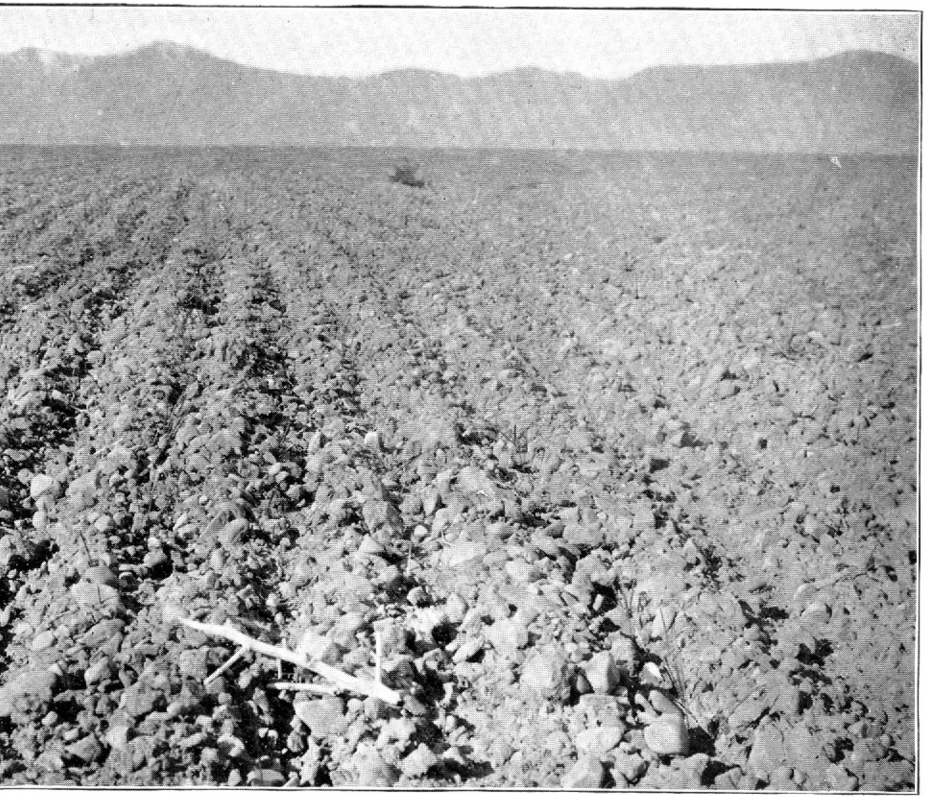
This type of soil is next in extent to the Jordan sandy loam, and comprises 60 square miles, or 24 per cent, of the entire district. Excepting about 2,000 acres immediately under the Utah and Salt Lake Canal, principally in the southern part of T. 1 S., R. 2 W., it all lies above the irrigation canals and is too elevated to be irrigated by any of the present water supply. There has been a scheme proposed for raising part of the water passing through the Jordan Narrows by hydraulic means and constructing another canal above and parallel with the Utah and Salt Lake Canal. The height to which it would be profitable to raise water for irrigation purposes by such means would take in only a narrow strip of this upland, owing to the steepness of the slope toward the mountains.

At Herriman there are about 100 acres irrigated by water taken from Butterfield Creek, and in the northwestern part T. 2 S., R. 2 W., there are a few small springs which serve to irrigate a very limited area. There are also a few small farms along Bingham Creek irrigated by its waters.

During freshets considerable water comes down from the canyons of the Oquirrh Mountains, and, in a few instances, some of it is diverted and used for irrigation. This, however, is very unsatisfactory, because at times when water is most needed no water is to be had. The only possible means of successfully irrigating any considerable area of this land is by storing the water from the mountain streams in reservoirs constructed for that purpose.

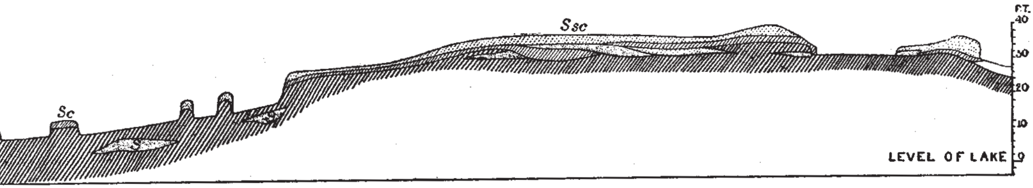
The Bingham gravelly loam comprises the area shown on the soil map by the brown color. It is always underlaid by gravel at within 3 feet of the surface, and the small gravel generally papears at the surface in greater or less quantities.

The following table gives the mechanical analyses of four samples of this soil to 12 and 15 inches in depth.

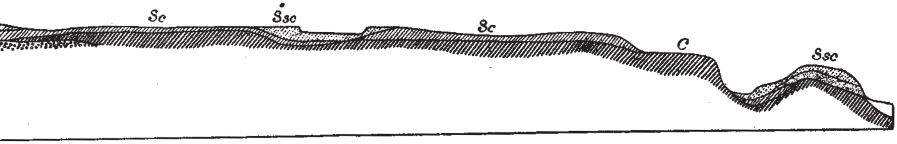


Bingham Gravelly Loam—Gravel 1 Inch in Diameter.

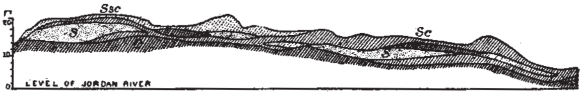
ype of soil is dry-farmed to wheat and in favorable seasons produces fair yields.



Section A–A.



Section B–B.



Section C–C.

y along lines marked on sketch map, page 103. (S = sand; Ssc = sandy loam; Sc = loam; C = clay; Gr = gravel.)

Mechanical analyses of Bingham gravelly loam soils.

No.	Locality.	Description	Moisture in air-dry sample.	Organic matter.	Fine gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.01 mm.	Fine silt, 0.01 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
4362	SW. ¼ sec. 15, T. 3 S., R. 2 W.	Rolling land 0 to 15 inches, 25.5 per cent coarse gravel.	2.25	3.96	1.50	2.71	5.81	8.87	27.93	28.08	5.13	13.53
4363	S. C. sec. 24, T. 2 S., R. 2 W.	Rolling land 0 to 15 inches, 9 per cent coarse gravel.	2.90	4.16	0.66	1.77	7.71	8.50	28.71	22.19	4.38	15.98
4312	SW. ¼ sec. 2, T. 2 S., R. 2 W.	Rolling land 0 to 12 inches, 54.5 per cent coarse gravel.	2.39	4.53	7.57	2.64	2.88	7.29	13.06	37.12	4.34	18.15
4313	SE. ¼ sec. 34, T. 3 S., R. 2 W.	Rolling land 0 to 15 inches, 4.4 per cent coarse gravel.	3.04	5.06	.33	.77	2.48	4.09	15.73	38.91	5.08	22.66

The analyses show the texture of the fine earth after all gravel larger than two millimeters in diameter has been taken out. The clay ranges from 13.5 to 22.6 per cent of the fine earth. The coarse gravel varies from 4.4 to 54.5 per cent. The gravel is small and more or less rounded and interferes little with the cultivation of the soil. Below 3 feet, and sometimes at even a less depth, the gravel becomes large and occasionally gives place to bowlders and rock. The most usual profile to 6 feet in depth is 18 inches of gravelly loam. underlaid by large gravel. This type of soil is usually free from noticeable amounts of salt, as will be seen by referring to the salt map. The native vegetation consists largely of sagebrush, with some rabbit bush, grass, tumble weeds, etc.

A considerable percentage of this type of soil is dry farmed to wheat. As a rule, the yield is small, but in years of abundant rainfall it sometimes exceeds 20 bushels per acre. The land slopes rapidly toward the mountains and has many deep washouts, which seem much larger than would be required for the natural escape of the drainage waters. These were probably formed by cloudbursts, which at some period visit most of the areas in the Bonneville Basin.

JORDAN LOAM.

This type of soil, while ranking third in extent, is perhaps second in importance, as it mostly lies within reach of the present irrigation water supply. It comprises about 50 square miles, or 20 per cent of the total area, and four-fifths of it lies below the present canal systems. Of this portion, however, there are numerous isolated areas, occurring in the area of clay flats near the shore of the lake, which, owing to their irregular forms, small size, and location would be relatively expensive to irrigate. The main body of this type of soil, how-

ever, could be easily irrigated and, as demonstrated by that portion now under cultivation in the irrigation district, would prove excellent land if put in proper condition.

This type of soil is shown on the soil map by the areas in solid red. It varies much in depth and underlying strata; the most usual profile, however, is 3 feet of loam, underlaid by clay which contains frequently pockets or strata of sand.

The accompanying table of mechanical analyses shows the texture of the surface foot in six localities and the character of the subsoil underlying two of them.

Mechanical analyses of Jordan loams.

No.	Locality.	Description.	Salt as determined in mechanical analysis.	Moisture in air-dry sample.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.05 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.01 mm.	Fine silt, 0.01 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
4331	NW. C. sec. 34, T. 1 N., R. 2 W.	Dry level land..	0.80	1.49	3.72	0.31	0.61	2.51	7.03	26.95	37.42	4.	14.70
4318	S. C. sec. 27, T. 3 S., R. 1 W.	Good alfalfa land irrig.	.56	2.30	5.05	.12	.16	.38	2.62	20.92	37.73	6.73	22.58
4324	S. C. sec. 18, T. 1 S., R. 2 W.	Low, wet by springs.	2.38	2.39	14.13	.10	.47	1.08	2.68	12.45	28.59	12.98	23.16
4325	NE. ¼ sec. 35, T. 1 N., R. 2 W.	Dry level land..	.81	2.35	4.89	T.	.17	.64	4.66	20.68	36.23	5.99	23.51
4364	N. C. sec. 4, T. 1 S., R. 2 W.	.....do..........	1.08	2.10	6.81	1.57	2.42	3.23	5.67	14.22	29.96	6.49	27.66
4336	NW. ¼ sec. 8, T. 1 N., R. 2 W.	Low uneven land.	1.76	1.07	8.57	T.	.56	1.25	7.45	33.70	12.46	1.06	31.80
	Subsoils under Jordan loams.												
4332	Loam 12 to 24 inches.	Under 4331.....	1.16	1.37	9.41	T.	1.47	2.10	6.53	24.81	30.58	2.38	21.04
4333	Very fine sand 24 to 36 inches.	.....do	.95	1.03	6.83	.....	.11	.66	7.78	42.67	27.04	1.85	11.91
4334	Sand and clay 36 to 48 inches.	.....do..........	1.25	.93	5.64	3.78	2.91	9.33	17.56	17.97	24.18	2.40	13.63
4335	Clay loam 48 to 72 inches.	.....do..........	1.59	2.18	8.16	1.26	.88	1.16	2.40	13.38	35.49	4.52	28.37
4372	Clay loam 12 to 24 inches.	Under 4364.....	1.74	2.64	9.22	.49	1.02	2.65	5.08	11.87	24.63	7.10	33.47
4372*a*	Clay loam 24 to 36 inches.	.....do..........	2.24	2.15	11.21	3.24	2.52	2.49	2.34	5.88	23.83	8.64	33.14
4373	Clay 36 to 48 inches.	.....do..........	2.24	2.10	10.23	T.	.41	.26	.41	7.33	24.46	9.23	44.38

The clay content varies from a minimum of 14.7 per cent to a maximum of 31.8 per cent. The latter amount is rather high to be classed as a loam, 30 per cent being usually taken as the upper limit for this class. This sample, however, was easily classed as a loam by the observer in the field, and the fact that it contains a lower percentage of silt and fine silt than any of the other samples analyzed for either this or the two preceding types of soil accounts for the apparent conflict between the analysis and the field judgment. The silt content, being unusually low, counteracts the effect of part of the clay, and therefore gives the sample the characteristics of loam. The mean clay content of 23.9 per cent for these six samples may be taken as representative of

this type of soil. The other large separations are under the heads of very fine sand and silt, which give 21.5 and 30.4 per cent respectively. The first four separations show a very small percentage in any of the samples.

Samples Nos. 4332–35, inclusive, show the texture of the subsoil to 6 feet in depth under soil No. 4331. The second foot is also a loam, but heavier than the first, which is on the border line between Jordan sandy loam and Jordan loam; next comes very fine sand, which continues about two-thirds of the way through the fourth foot, and below this is clay loam. This character of subsoil, while common under Jordan loam, is perhaps more characteristic of the first type of soil.

Samples Nos. 4372 and 4373 show the texture of the subsoil under soil No. 4364. Here the second and third feet are clay loam and the fourth foot clay. This is more characteristic of this type of soil than is the former subsoil, excepting that the overlying loam is of less depth than the average. Subsoils of this character are so heavy that ordinarily they would be rather expensive to drain, on account of the short intervals at which lines of tiles would need to be laid in order to prove effective.

The field observations here, however, show that the clay or clay loam subsoil is most usually inlaid by strata of fine sand varying from a fraction of an inch to a foot or more in thickness. While these strata are continuous for only short distances, yet they occur at such frequent intervals that they would undoubtedly be of material assistance if underdrainage were undertaken.

Soil No. 4324 occurs in an area wet by large springs and producing a luxuriant growth of salt grass, which accounts for the high percentage of organic matter. The apparently high percentage of organic matter in the heavier samples is probably in part water of crystallization, which is only driven off by temperatures higher than are required for moisture determinations.

On the lowland the Jordan loam lies slightly lower than the sandy loam. It has the water-table rather near the surface and carries a higher percentage of salt.

The accompanying table gives the percentage of salt in each foot to a depth of 6 feet for various places in this type of soil.

Table showing the per cent of salts at saturation at various places and depths in Jordan loam.

[Percentage calculated on water-free soil.]

No. of boring.	Depth in feet.							Depth to standing water.
	1.	2.	3.	4.	5.	6.	8.	
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Feet.*
275	0.07	0.07	0.08	0.09	0.10	0.07	....	10+
149	.05	.05	.06	.07	.07	....	....	....
447	.58	.23	.19	.19	.14	.18	....	1
138	.49	.21	.18	.16	.16	.17	....	3
127	.58	.41	.24	.15	.16	.16	....	3
375	2.07	1.44	1.13	.86	.82	.92	....	4½
623	.11	.09	.23	.54	.88	81	0.67	5½
624	.38	.95	1.17	1.38	2.04	2.36	....	6
343	.74	1.38	1.65	2.09	2.09	2.21	....	5½
649	1.43	2.37	2.60	3.45	3.66	3.37	....	6

Borings Nos. 275 and 149 are typical of the favorable conditions for this type of soil in the irrigated district. Nos. 447, 138, and 127 are representative of the conditions in the southern part of T. 1 S., R. 1 and 2 W., where seepage water has caused an abandonment of the land for farming. Here the water table lies within 3 or less than 3 feet of the surface, and while the total salt content to a depth of 6 feet is only about 0.25 per cent, yet in the surface foot it has accumulated to such an extent as to be fatal to some crops. By removing the water the soil would soon return to a productive state.

Boring No. 375 is in a low level area which is watered by large springs. At the time this determination was made the water had been turned off, and the water table was 4½ feet below the surface. Ordinarily it is much nearer the surface than this, and, in fact, the surface is frequently covered by water. The salt content is high and shows an accumulation at the surface, this being always a result of wetness. Nos. 623, 624, 343, and 649 show the range in salt content and its usual distribution on the lowland part of this type of soil when the water table is more than 4 feet below the surface. They all show the minimum amount in the surface foot, and a gradual increase as the depth increases. No. 623 shows an unusually small amount, 649 an excessive amount, and 624 and 643 normal amounts for this type of soil.

A comparison of the soil and salt maps shows that most of this type of soil which is on the lowland falls within the slate colored area on the salt map—i. e., it contains from 1 to 3 per cent of salt to a depth of 5 feet. Excepting about 2 square miles near the mouth of the Jordan River, none of it falls into the class containing more than 3 per cent; but on the other hand a small per cent falls in the class containing 0.6 to 1 per cent.

Like the Jordan sandy loam, this type of soil also frequently shows a comparatively small amount of salt in the surface foot, but as we descend it increases rapidly, and when the soil is put under irrigation the salts soon accumulate at the surface, unless by some means the water table is kept down and the surface evaporation reduced to a minimum by the best cultivation or by shading crops.

The larger percentage of this type of soil is capable of reclamation by underdrainage and washing, but at a somewhat greater outlay than would be required for the Jordan sandy loam.

JORDAN CLAY AND CLAY LOAM.

The next type of soil in order of extent is the Jordan clay and clay loam, which comprises about 35 square miles, or 14 per cent of the whole area. Excepting about 1,500 acres, one-half of which lies west of Williams Lake and the remainder southwest of Decker Lake, this type of soil lies from 4 to 8 feet lower than the land immediately adjoining. It is level and wet, and rarely contains any vegetation. It forms what was formerly the floors of lagoons near the shore of the lake and

often extends far back into the higher and better land. In other places it assumes the form of draws extending like wide irregular canals back into the land for miles. Its distribution is shown on the soil map by the blue color.

The accompanying table gives the mechanical analyses of two samples of soil and the subsoil under one of them to 6 feet in depth.

Mechanical analyses of clay and clay loam soils.

No.	Locality.	Description.	Salt as determined in mechanical analysis.	Moisture in air-dry sample.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.01 mm.	Fine silt, 0.01 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
4345	C. S. 18, T. 1 N., R. 2 W.	Salt flat	8.89	.....	11.51	3.94	4.91	2.92	2.28	14.10	19.15	4.23	25.67
4351	S. 30, T. 1 N., R. 1 W.	Low level land	2.04	2.63	6.39	.77	.90	2.03	4.37	20.68	27.46	4.35	28.18
	(Subsoil under 4345.)												
4346	Depth 12 to 24 inches.	Clay loam	11.47	2.10	13.65	7.19	6.17	4.94	3.52	7.28	22.78	4.47	16.86
4347	Depth 24 to 36 inches.	Yellow clay	7.82	11.02	12.96	4.14	1.88	2.66	1.16	5.47	23.53	3.45	26.87
4348	Depth 36 to 48 inches.	Red clay	5.92	8.24	8.43	2.58	1.06	.64	.54	8.41	27.19	3.74	35.23
4349	Depth 48 to 60 inches.	.....do	6.53	10.20	9.50	8.58	.41	.23	.28	3.27	24.02	3.38	33.50
4350	Depth 60 to 72 inches.	.....do	5.02	.....	5.32	.51	.29	.32	.50	14.42	30.04	10.80	33.74

Sample No. 4351 shows the texture of the small upland area just west of Williams Lake. It is very similar to the Jordan loam, which lies adjacent, but is slightly lower and somewhat heavier in texture. Its salt content to a depth of 6 feet is shown under boring No. 162 in the table giving salt content. The total salt content does not differ materially from that in the adjacent Jordan loam, but it shows an accumulation in the upper portions, which is not the case with the latter, where the water table lies at 6 feet, as it does here. The probabilities are that the water table is much higher under this soil during a portion of the season.

No. 4345 shows the texture of the clay loam of the flats, 20 per cent of this sample being under the heads of organic matter, and salt. Therefore the clay content should be increased from 25.67 to over 30 per cent, in order to show the real per cent of clay present in the soil alone. The subsoil beneath this is shown in Nos. 4346–50.

The accompanying table shows the per cent of salt for this type of soil:

Salt content at saturation for various places and depths in Jordan clays and clay loams.

[Percentage calculated on water-free soil.]

Number of boring.	Depth in feet.										Depth to standing water.
	1.	2.	3.	4.	5.	6.	8.	10.	12.	15.	
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Feet.*
132	0.14	0.11	0.12	0.13	0.12	0.12	......	......	......	......	2
162	1.18	1.23	1.12	.79	.68	......	......	......	......	......	6
355	5.58	4.95	6.30	6.41	5.22		4.44	2.96	1.86	.88	3
645	4.50	5.06	6.03	......	7.82	......	......	......	......	......	1½
646	10.60	9.80	11.40	10.30	9.80	9.30	......	......	......	......	2

Boring No. 132 gives the salt for each foot to 6 feet in depth for the area southwest of Decker Lake. The water table at the time of making this boring was only 2 feet below the surface, but the determination shows only a slight tendency to an accumulation of salt at the surface. In other portions of this area, however, the accumulation of the salt at the surface has caused the land to be abandoned.

Nos. 355, 645, and 646 give the salt content for three places in the barren clay loam and clay flats, and the amount present is simply astonishing. The above determinations show a range of from 4.5 to 11.4 per cent of salt in solution at saturation in the upper 6 feet of soil, and it is probable that at such concentration some of the salts may remain undissolved and are therefore not shown by the electrical method, which was used in their determination. Below 6 feet in depth there is a gradual diminution in the salt content, and in boring No. 355 it is only 0.88 per cent at 15 feet in depth. Boring No. 646 shows a very high salt content, the average to 6 feet in depth being 10.2 per cent. Allowing 70 pounds as the weight of a cubic foot of this soil, the amount of salt present, to a depth of 6 feet, in one square mile would amount to approximately 1,200,000,000 pounds. To the average mind such large numbers give no adequate idea of the real amount. By reduction we find that the 1,200,000,000 pounds equal 600,000 tons, which, at the rate of 20 tons each, would fill 30,000 cars. At 20 cars to the train this would equal 1,500 trains, or a continuous train of cars 180 miles long.

The agreement in area of this type of soil and the areas on the salt map showing 3 or more per cent of salt is almost identical. This type of soil being low, wet, salty, and of a clay nature, is not worthy of any notice for agricultural purposes at the present time. Those parts of it that extend far back into the better land form good drainage outlets for the latter and with very little improvement would serve to conduct drainage water to the lake.

JORDAN MEADOWS.

The Jordan Meadows comprise about 12 square miles, or 4.8 per cent of the entire area. They lie as a narrow strip, from a few rods to three-quarters of a mile in width, bordering on the Jordan River, and their usual elevation is only a few feet above the water in the river. Both the soil and the subsoil vary much in texture. The soil, however, is generally either a sandy loam or a loam about 2 feet in depth, which is underlaid by 2 feet of clay and this in turn is underlaid by sand and gravel. The soil is usually black, on account of the large amount of organic matter that it contains.

The following table shows the mechanical analyses of the soil from three places:

Mechanical analyses of Jordan Meadows soils.

No.	Locality.	Description.	Salt as determined in mechanical analysis.	Moisture in air-dry sample.	Organic matter.	Gravel 2 to 1 mm.	Coarse sand 1 to 0.5 mm.	Medium sand 0.5 to 0.25 mm.	Fine sand 0.25 to 0.1 mm.	Very fine sand 0.1 to 0.5 mm.	Silt 0.05 to 0.01 mm.	Fine silt 0.01 to 0.005 mm.	Clay 0.005 to 0.0001 mm.
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
4338	W. C. sec. 22, T. 1 N., R. 1 W.	River bottom, 0 to 24 inches.	1.05	1.18	5.90	T.	3.71	8.42	15.91	36.07	15.75	1.74	9.65
4337	SW. C. sec. 14, T. 1 S., R. 1 W.	River bottom, 0 to 12 inches.	1.96	1.89	9.23	T.	1.57	1.72	7.16	31.30	26.76	3.34	15.53
4339	E. C. sec. 14, T. 3 S., R. 1 W.	River bottom, 0 to 12 inches.	1.68	4.85	11.61	.21	.82	3.01	6.87	19.41	30.84	5.96	16.92

This type of soil was the first irrigated on the west side of the river, but wherever irrigation has been practiced above this land the seepage waters have come down and caused much damage. At present very little of it is farmed, but it often furnishes good pasture.

The accompanying table gives the salt content to a depth of 6 feet in three localities. The salt while not present in excessive amounts is sufficiently high to be harmful and is sometimes even fatal to ordinary crops. There is a tendency for it to accumulate at the surface.

Salt content at saturation for various depths and places in Jordan meadows.

[Percentage calculated on water-free soil.

No. of boring.	Depth in feet.						Depth to standing water.
	1.	2.	3.	4.	5.	6.	
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Feet.*
5	0.37	0.76	0.40	0.31	0.36	0.35	3½
637	0.55	0.51	0.49	0.55	0.35	0.30	6
281	0.73	0.67	0.36	0.29	0.27	0.18	5

JORDAN SAND.

These sands constitute a marginal area along the bluffs just above the Jordan meadows, and are found in a few isolated areas on the upland. They are shown on the soil map in yellow. It is fine sand

Bingham Stony Loam, looking toward the Lake Shore.

This stony loam can not be cultivated.

usually to a depth of 6 feet or more, although occasionally occurring as an overlying stratum only 1 or 2 feet in depth, covering sandy loam or loam. In places it drifts about as dunes, and is usually so located as to be difficult to irrigate, therefore it is not much used for agricultural purposes. Where irrigated it requires large amounts of water to cover any considerable distance, and as a consequence, accumulations of seepage waters on low adjacent areas are the rule. Owing to the leachy character and good underdrainage, it seldom contains much salt.

BINGHAM STONY LOAM.

This loam occurs above all canals, and constitutes a small area near the foothills of the Oquirrh Mountains, shown on the soil map by the brown color. It consists of a thin layer of sandy or gravelly loam, underlaid by bowlders, rock, and conglomerate, which frequently outcrops, from a few inches to the height of a man, at the surface. It is too stony for cultivation.

SALT LAKE SAND.

This sand is a product of Great Salt Lake, and consists of spherules about the size of No. 10 shot, which are made up almost wholly of carbonate of lime. The accompanying table shows the mechanical analysis of a sample of this sand taken from the dunes along the lake shore. It is known as oolitic sand, because it resembles the petrified eggs of fish. Whether the spherules as such were formed in the process of separating from the water or whether they were formed by the action of the wind and water, from the broken fragments of lime-carbonate hardpan that occur in great quantity along the shore, was at first a matter of conjecture.

Mechanical analysis of Salt Lake sand.

Diameter.	Conventional name.	4355. Shores of G. S. L.
Millimeters.		
2 to 1	Fine gravel	0.62
1 to 0.5	Coarse sand	2.35
0.5 to .25	Medium sand	81.25
.25 to .1	Fine sand	15.32
.1 to .0001	Very fine sand—silt and clay	.51

Upon examining the different separations in the laboratory, however, it was found that the portion classed as fine gravel consisted of quite angular broken fragments of lime carbonate, the angles slightly rounded by erosion. The particles of the next grade—coarse sand—were much more rounded, although the larger ones were still quite angular, as could be seen by the naked eye. The third grade—medium sand—included over four-fifths of the sample, and in this all of the particles were well rounded, there being no angular ones. Under the microscope the most of these particles proved to be almost perfect spheres, while a smaller proportion of them were oblong or egg shaped. The

surfaces were quite smooth and highly polished. The fourth grade—fine sand—was similar to the third, but more of the particles were oblong and a few of them somewhat cylindrical, while the small percentage remaining in the class of very fine sand was chiefly angular particles of very fine sand and silt with just a trace of clay, the material being siliceous, not carbonate of lime. All of the particles, except those of the very fine sand, when treated with dilute hydrochloric acid give rise to a violent ebullition of carbon dioxid and soon disappear, leaving behind only a small flocculent precipitate, which, under the microscope, is shown to be clay particles with an occasional angular particle of silt. There seemed to be no nuclei to the lime carbonate particles, and all the evidence points to their formation by the breaking up of the thin pieces of lime-carbonate hardpan, which is quite abundant. These broken pieces, when sufficiently cubical, afterwards become rounded by the action of the water and the wind. Where the particles of lime-carbonate hardpan are flat they do not take on a rolling motion, and consequently do not become rounded. The particles are sufficiently soft to be easily crushed by pressure with a knife blade. It forms an insignificant area along the shore, either as dunes, which in some places reach 10 or 12 feet in height, or spread out on the beach and on the slightly elevated areas near the lake shore as a layer of from a few inches to several feet in depth. Whatever its mode of formation, the material evidently comes from the lake water, which has reached the saturation point in regard to carbonate of lime.

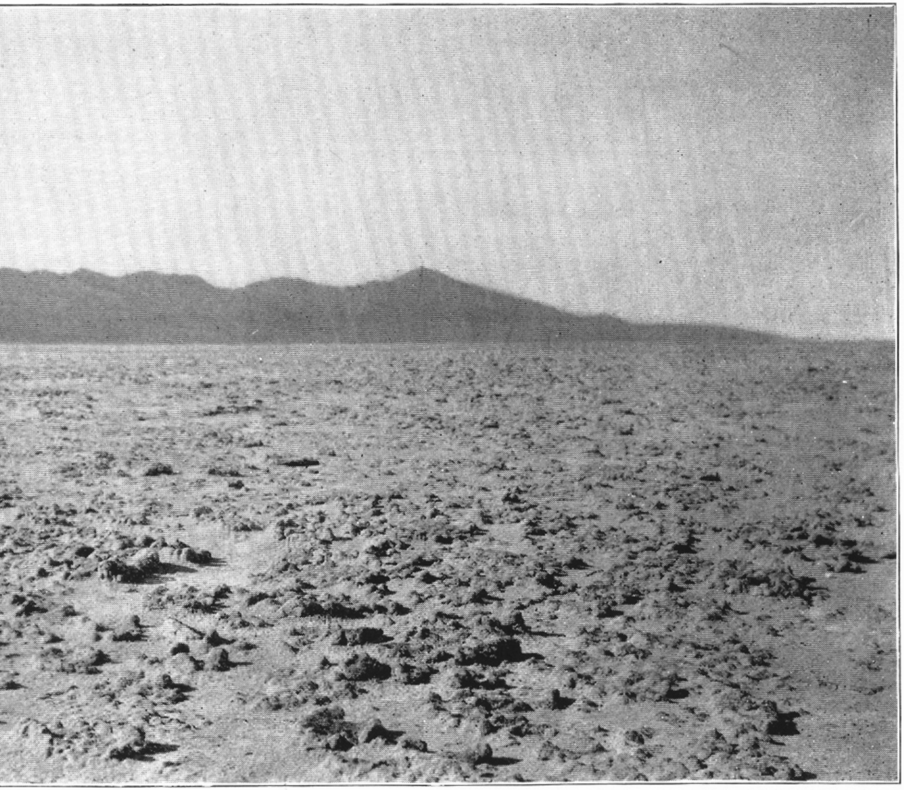
HARDPAN.

The sketch map of the valley on page 103 shows a number of small areas of hardpan on the level lands between Salt Lake City and Great Salt Lake. This formation occurs over an aggregate area of about 12 square miles. The hardpan usually occurs under the Jordan sandy loam. This material is encountered at from 12 to 30 inches below the surface and at an average depth of 18 inches. It is from 2 to 18 inches thick, and averages about 3 or 4 inches.

The texture of the hardpan is the same as the material immediately above and below it, but this layer has been cemented by lime carbonate. Under ordinary conditions it is quite pervious to water and to the roots of plants, but when dry it is quite hard and difficult to dig. When moistened with water and soaked for a while it softens considerably, but does not disintegrate to any appreciable extent. It effervesces freely with hydrochloric acid and falls apart into a sandy loam.

As would be expected, the subsoil immediately below the hardpan is quite moist throughout the season, while above it the soil is quite dry during the summer months. The soil above the hardpan is usually free from excessive quantities of alkali, while below the hardpan the salt content is very much greater.

On the shores of the Great Salt Lake very interesting observations



ION OF HARDPAN ON THE SHORES OF THE LAKE WITH DECOMPOSING ALGÆ BEING INCRUSTED WITH CARBONATE OF LIME.

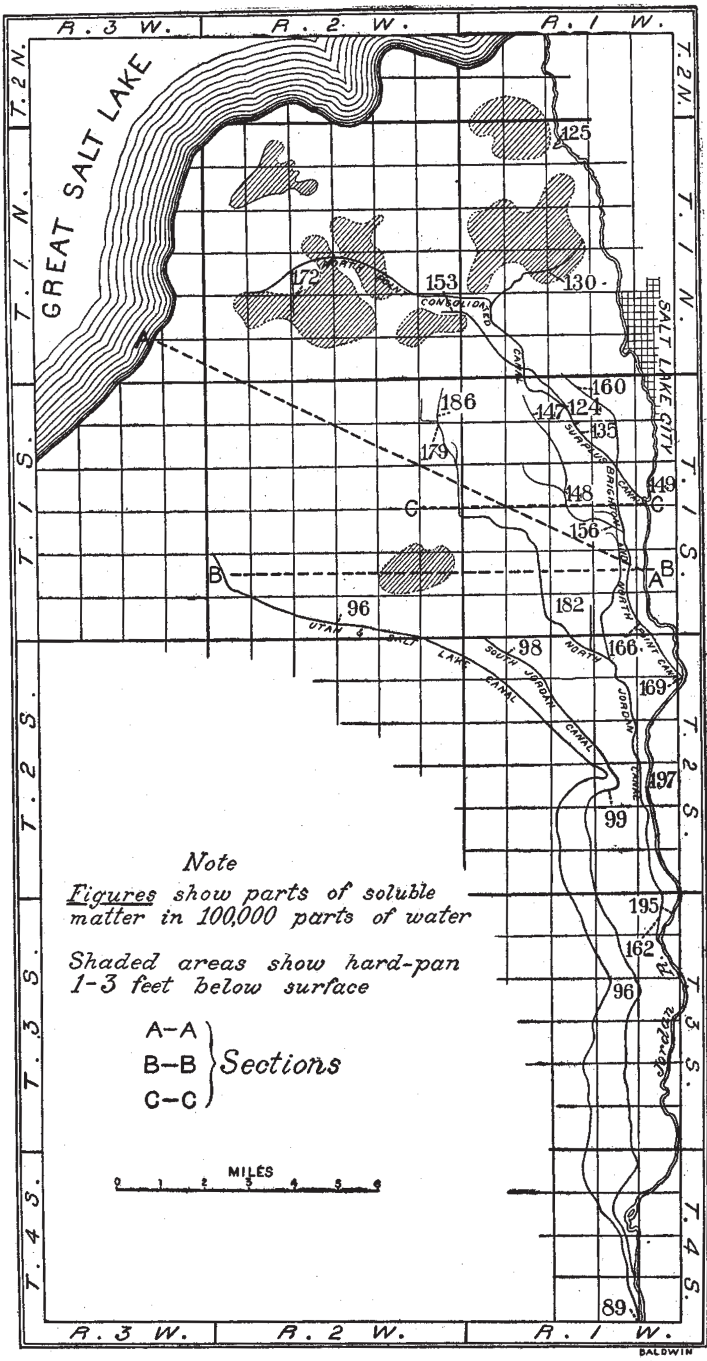


FIG. 10.—Sketch map of western part of Salt Lake Valley, showing canals, hardpan areas, and parts of salt in 100,000 parts of river and irrigation waters.

were made on hardpan forming on the surface and in all stages of formation. The preliminary stage was the washing up of algæ from the lake and of immense quantities of the salt shrimp, which lives in the lake waters, on to the beach. These gradually become crusted over with various salts, which, after repeated leaching, leave only the difficultly soluble lime carbonate. As the organic matter decomposes it is replaced with the lime carbonate, until the mass finally assumes the character of thin strata of broken limestone rock, nearly covering the surface over considerable areas.

Dr. Cameron has examined this material and has made the following interesting statements upon its probable mode of formation:

The samples collected on the shores of the lake by Mr. Gardner suggest some very interesting ideas as to the formation of hardpan. The samples all show the presence of calcium carbonate as such, more or less densely compacted, and there can be no doubt that this material is the cement holding together the other constituents which go to make up the hardpan. Calcium, in some form of combination, is present in the water of the Salt Lake. From an analysis made by Dr. J. E. Talmage in 1889 there appeared to be 0.084 per cent of calcium in the water, and it seems reasonable to suppose the amount is no less at the present time. The original source of the lime was probably in gypsum or carbonate of lime, and for our purpose it is a matter of indifference which it was. Gypsum (or the carbonate of lime either) is but slightly soluble in water free from other salts. But the presence of another salt markedly influences its solubility. If sodium chlorid be present, we shall have in the solution some sodium chlorid, some sodium ions, and some chlorin ions, thus:

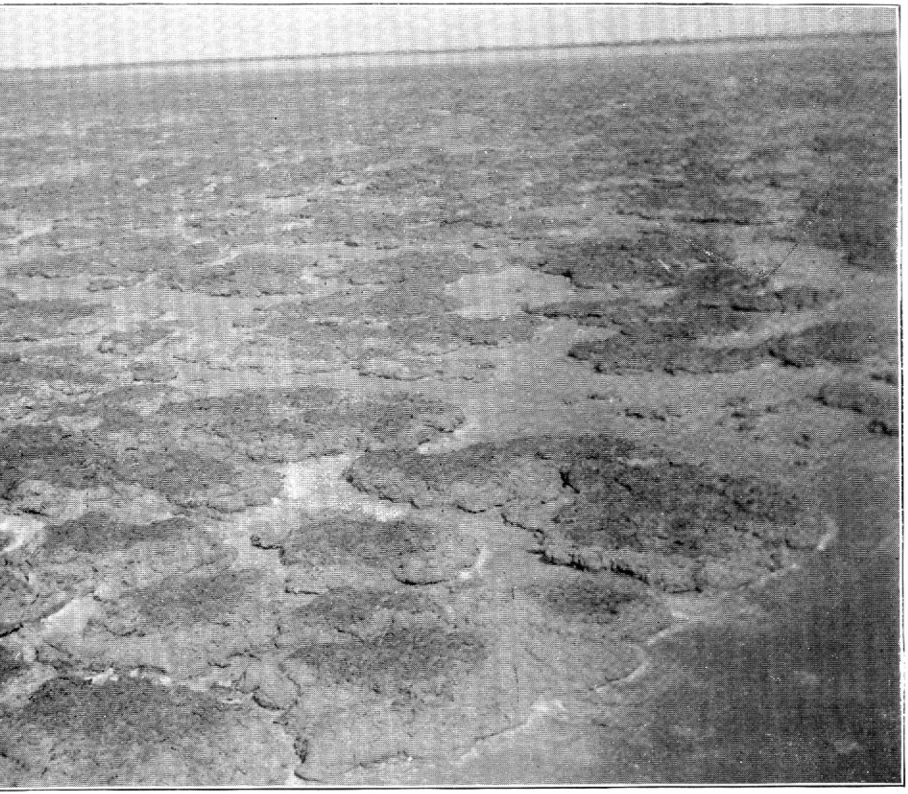
$$\mathrm{NaCl} \quad \overset{+}{\mathrm{Na}} \quad \overset{-}{\mathrm{Cl}}$$

When the calcium sulphate is brought into contact with the solution we will get at once and in the same way calcium sulphate, calcium ions, and sulphions in the solution:

$$\mathrm{CaSO_4} \quad \overset{+}{\mathrm{Ca}} \quad \overset{-}{\mathrm{SO_4}}$$

But the sodium ions and the sulphions present will unite to a certain extent to form sodium sulphate. At once there is a tendency for the sodium chlorid to furnish more sodium ions and the calcium sulphate to furnish more sulphions to restore the equilibrium. In the same manner the calcium ions and the chlorin ions will unite to form the very soluble calcium chlorid in the solution with a corresponding tendency to the formation of further calcium and chlorin ions. While the gypsum is but sparingly soluble, all these other salts formed are quite soluble, and more and more of the gypsum will dissociate and go into solution until equilibrium be reached. If the sodium-chlorid solution be at all concentrated, it has been shown that the amount of gypsum soluble in it is astonishingly large. In this way it is easy to see how lime salts could be carried down to the lake. But just as the presence of a salt increases the solubility of another without a common ion, it decreases the solubility of the second salt if they both yield a common ion. Of all the possible salts which may form in a solution when in instable equilibrium as regard saturation, that salt which is the least soluble will, of course, be precipitated. Thus it is that the waters of the Salt Lake containing large amounts of soluble sulphates, practically saturated with respect to them in fact, contain but a very small amount of calcium.

Moreover, the water of Salt Lake has been shown in this laboratory to contain a small amount of carbonate, either calcium carbonate or, much more likely, sodium carbonate. This fact is not recorded in any of the published analyses of the water, so far as I know, and as a matter of fact this need not cause any surprise under the



DVANCED STAGE OF FORMATION OF HARDPAN ON SHORE OF LAKE.

circumstances. Its presence was discovered almost accidentally. Mr. Gardner had attempted to test the water for alkalinity by adding phenolphthalein solution. No color whatever was apparent, but on throwing the contents of the vessel away and attempting to rinse with distilled water a marked alkaline reaction was observed in the wash waters. Investigation showed the absence of any alkali in the distilled water. An examination in this laboratory brought out the explanation of the phenomena very clearly. There is sodium carbonate in the solution, and normally this would dissociate with the formation of sodium ions, which could be detected by the phenolphthalein. But the water contains so large an amount of salts with sodium ions that the solution is saturated with respect to this ion, and, carbonates being salts of a weak acid—that is, with a relatively small tendency to dissociate—the dissociation of the sodium carbonate is completely "driven back." Consequently there is no dissociated sodium carbonate in the solution. On the addition of more water, however, the concentration of the solution with respect to the sodium ion is decreased, more sodium ions may be formed, and the sodium carbonate dissociates, which fact is indicated by the phenolphthalein solution. This explanation was verified by repeated experiments with the water from the Salt Lake and with brines containing traces of sodium carbonate, prepared artificially. There is the further interest in these facts, that the absence of lime carbonates in the lake water has been the subject of much interest and speculation. The explanation is apparent from what has just been said. As the conditions are such that practically no dissociated calcium sulphate or dissociated calcium carbonate can exist, the water will only take up so much of these salts as is soluble without dissociation, somewhat less, in fact, than if the other salts were not present in the water.

At the edge of the lake the spray carrying various salts in solution falls on bunches of algæ and other organic matter, and, the water evaporating, the salts contained are precipitated. Theoretically the first to separate should be the small amount of calcium carbonate present, and in a general way this is probably so, but it is more or less mixed with the other salts. These other salts, being more soluble, are partially restored to the lake by the returning drip, by washing with rain water, etc., and the calcium carbonate already deposited will hasten the precipitation of more calcium carbonate from successive washings of spray, and thus it will gradually accumulate. In the specimens of the most recent formation collected by Mr. Gardner these views are well exemplified. In water, either cold or hot, the material is partially disintegrated and dissolved, fragments of the algæ (green and well preserved) being obtainable from the residue, as well as small twigs and other organic matter. The contents of the water solution appears to be in the main sodium chlorid, though other salts might be found on a careful examination. The solution showed the presence of but little lime and did not effervesce noticeably on the addition of an acid. The residue insoluble in water proved to be nearly entirely carbonate of lime, a very small residue being left after treatment with dilute hydrochloric acid.

Farther back from the water's edge specimens were obtained, consisting of twigs, grasses, etc., dead organic matter, bound together with a material which proved on examination to be nearly all calcium carbonate, though there appeared to be quite a small amount of sodium chlorid and other salts present. On treatment with dilute hydrochloric acid, besides the dead organic matter there was a small residue of fine sand or silt left. This hardpan, while much harder and more compact than the one first described, is still sufficiently friable to be broken with the fingers, though with some difficulty, and is fairly porous. It can be regarded as representing a subsequent stage or later development of the first described specimens. The sodium chlorid and other water-soluble salts have been gradually washed out and returned to the lake. The calcium carbonate, by alternate redissolving and reprecipitation, has become more dense and compact. In this process the sodium chlorid may have been an important factor. It would seem quite probable that the dead organic matter might play a decided rôle in yielding by oxidation carbonic acid. This carbonic

acid, in the presence of moisture, would dissolve the lime carbonate with the formation of the bicarbonate, and the bicarbonate, in turn, would reprecipitate as the carbonate on drying. Still farther back from the water's edge was found another type of material, evidently representing a later stage in the genesis of hardpan. This material appears to be but very slightly affected by treatment with water. It is practically all soluble in moderately dilute hydrochloric acid, a small residue of light brown silt remaining. The cementing material proves to be almost entirely lime carbonate with, perhaps, some magnesium carbonate. It is quite dense and compact and noticeably free from the undecomposed organic matter in the specimens last described. It evidently represents a later product of the process of resolution in carbonated water, reprecipitation on drying, and may fairly be taken as the type of the final product in the genesis of a lime carbonate hardpan.

On the shore between the two deposits last described (or still farther back in the form of wind-blown dunes) are found great quantities of small, remarkably well-rounded spherules, whose composition appears to be either entirely calcium carbonate or calcium carbonate about a very small nucleus of sand or some siliceous mineral. Several hypotheses have been suggested as to the origin of this material, but so far none seems to have received much credence. I am inclined to think they originated from the forming hardpan on the shore, by the action of waves during rough weather, by splitting up of the parent material by frost, the result of wind action, or of all these agencies. Their rounded form is quite easily accounted for in two ways—as the result of rolling from the action of the water; by the etching due to the solvent effect of the water, it being a well demonstrated fact that in the absence of any special reason to the contrary the result of such action is always to round off the edges and produce a spherulitic form, thereby reducing the surface, and consequently the "active mass," to a minimum. The striking uniformity in the size of the particles may be taken as confirmatory evidence of the views just presented. Suppose the particles to have been originally of widely varying masses. At such times as they would have been under the influence of the water they would have been stirring about in a heavy, rather viscous brine, whose specific gravity would not be very far from that of the carbonate particles. Naturally the heavier particles would gradually accumulate at the bottom, the lighter ones at the top, and, as the turbulent actions ceased because the particles had practically the same shape and density, those of equal mass would have equal volume and would settle at the same time. The larger particles at the bottom might well be expected to gradually consolidate if left undisturbed for sufficient time, and some specimens collected by Mr. Gardner indicate that such action has taken place.

WATER SUPPLY.

The main water supply for the western part of the Salt Lake Valley is derived directly from the Utah Lake and delivered through the Jordan River, the distance between the lake and the Jordan Narrows, where the later canals are taken out, being about 6 or 7 miles.

Utah Lake is a large body of fresh water, having approximately 125 square miles of surface, but rather shallow. It is fed by rather short mountain streams, derived largely from melting snow. The water in these streams is of excellent quality and quite free from salts. The water of the lake itself contains rather more alkali, as the seepage from the surrounding lands—both irrigated and nonirrigated—sensibly affects the salt content. In the spring of 1899 Mr. Means found the salt content of Utah Lake to be about 50 parts in 100,000. In a shallow lake with such an extensive surface area the effect of evaporation during the summer must sensibly increase the concentration of the salts in the

water. This probably accounts for the difference of the salt content of the lake, as observed by Mr. Means in July, and the 89 parts per 100,000 at the Narrows in the Jordan River, observed about the 1st of October by the writers.

There are seven canals taken out of the Jordan River between the Jordan Narrows and Salt Lake City for irrigation purposes, besides three or four small canals for water power. Five of the irrigating canals are on the west side of the river, but only three of these are at present used to any considerable extent for irrigating purposes.

The total flow of water in the Jordan River at the Narrows has been variously estimated at different periods between 1895 and 1899 at from 244.2 second-feet to 526.3 second-feet, the information being obtained from the office of the city engineer.

The North Jordan Canal was the first one of the great canals constructed on the west side of the river. It is taken out of the river about 9 miles below the Jordan Narrows. McAllister made a number of measurements in 1895–1897, inclusive, and found the flow in the canal to vary from 50.3 to 103.7 second-feet. This canal is about 14 miles long.

The next canal constructed on the west side of the river was the South Jordan, which is taken out of the Narrows, and is about 16 miles long. Various measurements have been made by a number of observers from 1895 to 1899 of the flow in this canal, and the results vary from 40.4 to 166.6 second-feet, with an average flow of about 75 or 80 second-feet.

The Utah and Salt Lake Canal, which is about 50 feet above the last-named canal, is also taken out of the river at the Narrows and is about 23 miles long. The measurements in this canal at different times and by different observers vary from 49.8 to 185 second feet, with an average of considerably more than 100 second-feet. A considerable part of this, however, amounting at times to 50 per cent, is used by the power plant which supplies an electric current to Bingham and Mercer and returns the water directly to the river.

Observations made in 1899 show an estimated flow on June 4 for all canals taken out of the Jordan River of 526.3 second-feet; on August 18 of 325.6 second-feet; and on September 22 of 325.8 second-feet.

Besides the three principal canals used for irrigation on the west side, there are two others, namely, the Brighton and North Point and the North Point Consolidated, which were intended for irrigating the low land west of Salt Lake City, but which are hardly used at all at the present time. The North Point Consolidated Canal has a capacity of about 100 second-feet; the Brighton and North Point Canal is much smaller. There was enough water flowing past the intake of these canals during the summer of 1899 to have supplied their full capacity.

An analysis was made by Dr. Cameron of the solid matter of a sample of water from the Jordan River near the Narrows and of another

sample taken from the Jordan River opposite Salt Lake City. The following table gives the result of these analyses:

Kind and amount of salt in Jordan River water as determined by Dr. Cameron.

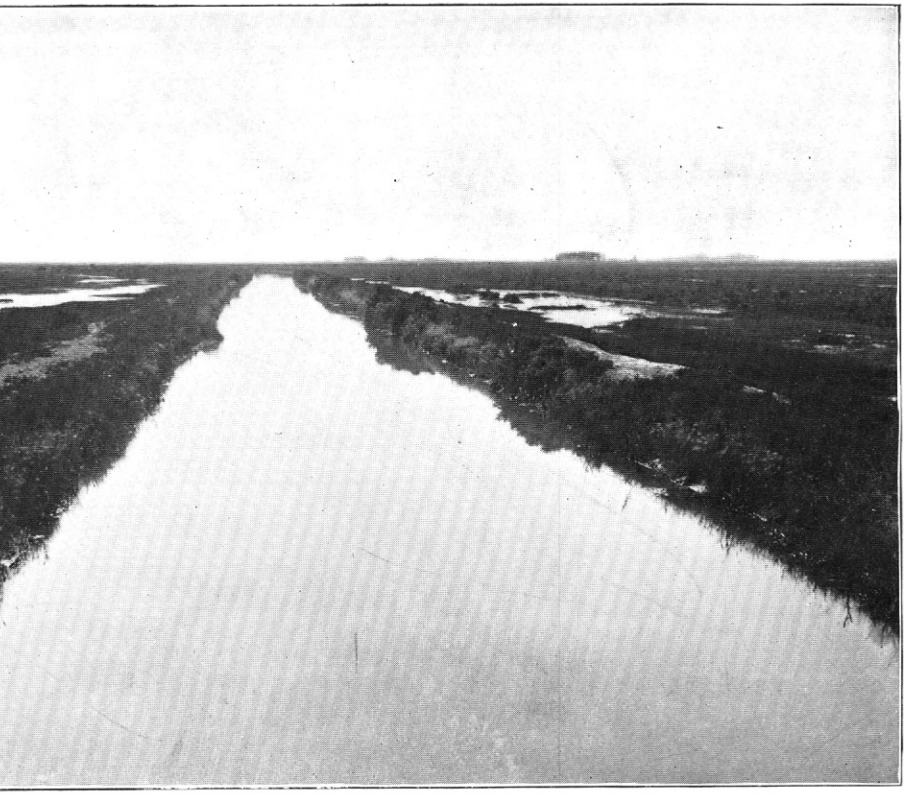
Kind of salt.	At intake of Utah and Salt Lake Canal, October 2.		At Salt Lake City, October 30.	
	Parts of salt in 100,000 parts of water.	Per cent of total salts present.	Parts of salt in 100,000 parts of water.	Per cent of total salts present.
Na_2CO_3	4.2	4.71	Trace.	....
$CaSO_4$	23	25.78	38	34.86
Na_2SO_4	11	12.33	9.8	8.99
$MgCl_2$	5.4	6.06	5.4	4.96
NaCl	45.6	51.12	55.8	51.19
Total	89.2	100	109	100
Residue dried at 105° C	98	....	118.4	....
Water of crystallization by difference	8.8	....	9.4	....

The sketch map of the valley (page 103) gives the total salt content in parts per 100,000 as observed during the progress of the survey in different parts of the valley. It will be observed that there is considerable fluctuation in the salt content of the river between the Narrows and Salt Lake City. This is dependent on two causes. On the east side of the river there are a number of mountain streams which deliver a considerable volume of snow water to the Jordan River, thus improving the quality of the water by dilution. On the other hand, there is a large amount of seepage waters collected by the river from the lands on either side, and, as these waters are generally highly charged with alkali salts, the salt content of the river tends to increase. Without this explanation of the conditions prevailing it would seem strange to see a salt content at the Narrows of 89 parts per 100,000 and this increased, at a point about half way to Salt Lake City, to 197 parts; at the intake of the surplus canal it is 149 parts, while at a point only two or three miles from the mouth of the river the salt content is 126 parts per 100,000.

The increase below the Narrows is to be ascribed entirely to the seepage from the adjoining irrigated lands on either side, while the comparatively low salt content near the mouth is due to the large volume of purer mountain water delivered by the several creeks which empty into the Jordan River at Salt Lake City.

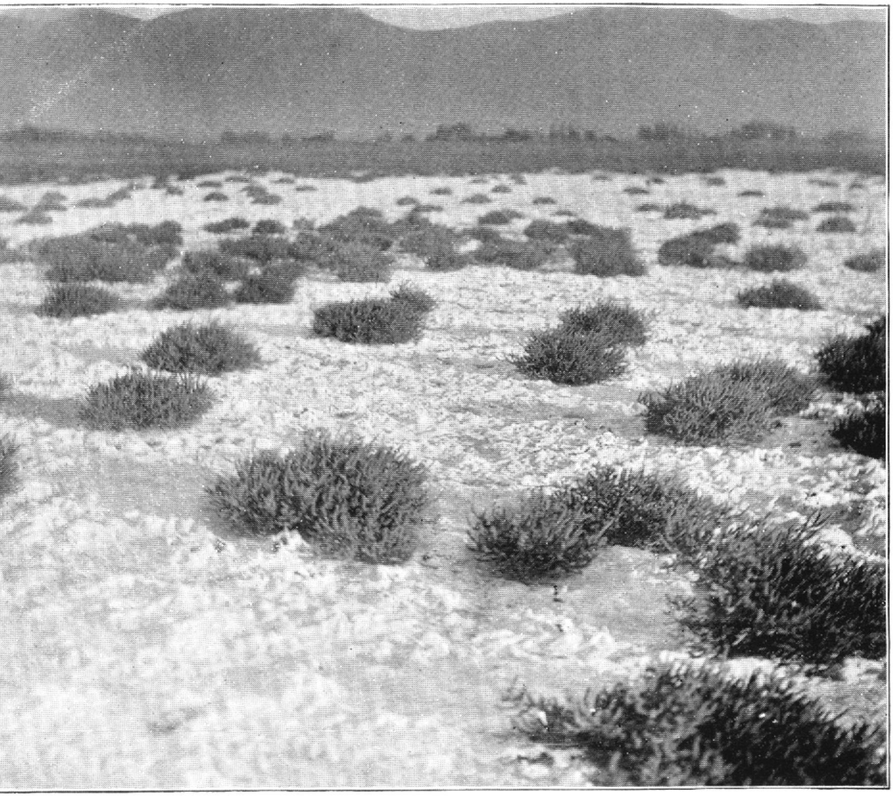
The sketch map shows the salt content of the water in the irrigation canals so far as observed during the course of the survey. These measurements cover a period of four months.

For plants growing with their roots immersed in water, i. e., grown by water culture and not in the soil, the limit of endurance is about 1 per cent, or 1,000 parts of salt per 100,000 parts of water. A soil containing 0.4 per cent of salt, saturated with pure distilled water, would have in the soil moisture a concentration of 1 per cent. As all of these soils contain more or less alkali, and as evaporation and consequent



INT AND CONSOLIDATED CANAL SHOWING SEEPAGE ALONG SIDES OF CANAL.

adjoining lands from the improper construction of canals. This is the source of the greatest injury to the lands in the valley.



LAST STAGE OF VEGETATION WITH ACCUMULATION OF ALKALI.

The last stage of vegetation is small annual saltbushes.

concentration set in immediately after the application of water to the land, it is unsafe to use water having a concentration greater than about 250 or 300 parts per 100,000 for irrigating the lands.

According to this standard it will be seen that all of the canals deliver water of a good quality for irrigation purposes, especially the higher canals. The Utah and Salt Lake Canal contains only about 95 parts of salt per 100,000 parts of water, the South Jordan Canal contains hardly more than this, while the North Jordan Canal contains nearly twice as much, but is still well within the limit of safety, at least so far as immediate effects are concerned. The limit of safety is dependent upon so many things—such as the salt content of the soil, the texture of the soil, the drainage, kind of crop, the stage and condition of cultivation, and the climatic conditions—that only very general figures can be given for such broad application.

APPLICATION OF WATER.

The three principal canals on the west side of the river with which we have to deal are the joint property of the owners of the irrigated land, each man having shares in proportion to the amount of land owned. Anyone not holding shares can rent water rights from those who own more shares than they have personal need of. The water is generally apportioned among the landowners in proportion to the stock they control. The exact amount of water used per acre in this district has not been determined; but the average for the State of Utah is estimated at about 1 second-foot for each 100 acres. There is generally an abundance of water in the canal; but when there is any deficiency all suffer alike in a reduced supply. The water is allowed to run continually throughout the season and the excess runs onto uncultivated or pasture land. There is believed to be more water used at times of abundant flow than is absolutely necessary. Furthermore, the high-land canals run for a portion of the distance through very pervious gravelly loams. The seepage and waste waters from the canals account in great measure for the 10 square miles of good land which has already been ruined by seepage and alkali. It has been shown that the water is of good quality and the lands of the upper benches are naturally free from any great excess of alkali; but the continual seepage from the canals during the growing season for a great many years has transported a quantity of salt to the lower levels.

The necessity of careful construction of the canals, especially those on gravelly lands, and the desirability of preventing the waste water from flowing over the lower levels is sufficiently obvious without further comment.

The application of water on the low lands west of Salt Lake City, where there is a large amount of alkali in the lower depth, has been attended with very disastrous results to crops. The salt has quickly

risen to the surface and, even where the surface foot was originally free from alkali, the crops have been completely ruined in the course of two or three years.

A very serious feature of the prevailing practice is that the land upon which an excess of water is used, or the land adjacent to a leaking ditch, is often not injured for a while and may even be improved by the excess of seepage water; while the lands at the lower levels, perhaps under the second or third ditch, may receive the full effect of this pernicious practice or condition.

The advisability and even necessity of State legislation, to compel the ditch owners to guard against undue seepage and to prevent the property owners from using excessive amounts of water in irrigation, is sufficiently obvious to require no further comment at this place. Property owners whose lands are damaged by either of these means should be able to recover damages in civil suits.

UNDERGROUND WATER.

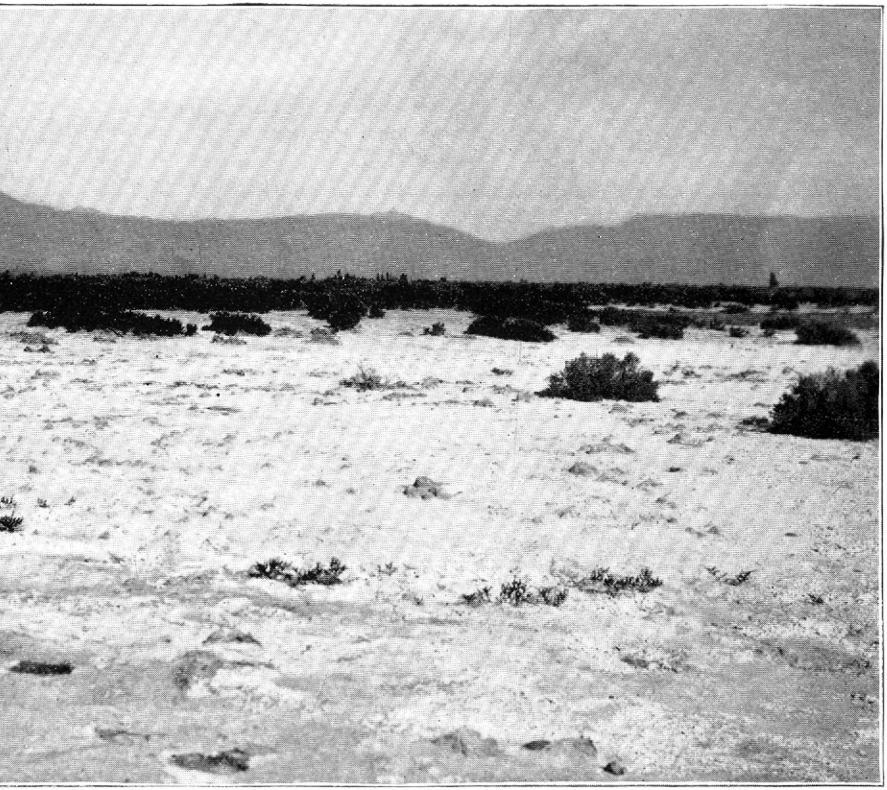
One of the maps accompanying this report gives the depth to standing water at the time of the survey. One of the three shades of green shows the area upon which standing water is found within 3 feet of the surface of the ground; another shows the area where the water is between 3 and 10 feet of the surface, and the third color shows where it is below 10 feet.

With standing water within 3 feet of the surface of the soil it is in no condition for any of our agricultural crops. Such areas must be drained in order to use the land for agricultural purposes. With water within 3 to 10 feet of the surface there is always more or less danger in the application of irrigation water. It is incumbent upon the owers of such land to watch the fluctuation of the underground water and to underdrain wherever necessary.

The texture of the soil, and especially the character of the subsoil, will largely determine the extent of the danger to be feared. The large areas south of Salt Lake City and the areas along the Jordan River with standing water within 3 feet of the surface are believed to be due entirely to seepage from the canals and from the irrigated lands above.

The underground water map shows, therefore, the areas which require immediate drainage to relieve the soil of surplus water. It is incumbent upon all those living within the areas colored medium and dark green to provide adequate drainage when the danger from underground water becomes imminent.

One of the pernicious effects of the accumulation of seepage waters is that the soil is made closer and more difficult to drain, therefore artificial drainage can be more economically and effectively applied before, rather than after, the collection of seepage waters near the surface.



ALKALI FLAT—TOO STRONG FOR SALTBUSHES.

will not grow where the salt content in the top 6 feet of soil approaches 3 per cent.

ALKALI IN SOILS.

The following table gives the composition of the alkali in the soils and crusts from a number of localities, as determined by Dr. Cameron. It will be seen that the sodium chlorid constitutes from 50 to 97 per cent of the total salts. The next largest constituent is sodium sulphate. The calcium sulphate is a difficultly soluble salt, and when the water evaporates this will be deposited in the soil as harmless gypsum which will not readily go into solution again. The other salts are all quite soluble and are liable to accumulate and concentrate in the soil moisture upon evaporation of the water from the surface of the land.

Chemical composition of salts in crusts and soils as analyzed by Dr. Cameron.

No.	Locality.	Na_2CO_3.	$CaCl_2$.	$MgCl_2$.	$CaSO_4$.	$MgSO_4$.	Na_2SO_4.	NaCl.
4366	S. 1, T. 1 S., R. 1 W		0.77	0.38	1.98			96.90
4381	3 miles northwest of S. L. C.	0.96			.79	0.25	31.15	66.84
4382	S. 32, T. 1 N., R. 1 W	9.28			1.06	.37	43.12	46.17
4383	S. 14, T. 3 S., R. 1 W			10.41	13.24	3.16		73.18
4384	S. 24, T. 1 S., R. 2 W	Trace.			2.14	.12	11.97	85.94
4385	S. 2, T. 1 S., R. 1 W	Trace.			6.38	29.87	8.29	55.48
4386	S. 16, T. 1 S., R. 3 W	Trace.		6.21	3.72	.75		89.31
4387	S. 29, T. 1 S., R. 1 W	.23			7.43	22.61	9.75	59.98
4388	Chambers, 2 miles east		7.62	10.37	9.97			72.04
4389	S. 4, T. 1 S., R. 1 W	.30			.25	.71	49.43	49.30
4390	S. 1, T. 1 S., R. 2 W			4.77	9.32	2.64		83.26
4391	S. 14, T. 3 S., R. 1 W	Trace.			7.33	32.32	9.86	54.49

The amount of alkali was determined by the electrical method in every foot down to at least 6 feet in depth. The alkali map represents what may be considered the average conditions, according to the judgment of the observer. If a boring showed a small amount of alkali in the surface foot and a large amount in the remaining depth the soil was classed as unfit for cultivation, as it would require but one or two applications of water to bring an excessive amount of salt to the surface.

Attention is called to the very large accumulation (over 3 per cent) of soluble salt in certain areas in the land west of Salt Lake City. There is a general agreement between the alkali map and the soil map, as would be expected, but this is influenced to a considerable extent by the topography of the country. The heavy clay soils and the land having this material within a short distance of the surface have generally the largest accumulation of alkali, on account of the imperfect drainage. The soil of the uplands is naturally free from excessive amounts of alkali, while the level area between Salt Lake City and the Great Salt Lake contains excessive amounts of salt. This latter fact is undoubtedly due to the influence of the Great Salt Lake, which, within comparatively recent years, covered much of this area. There are no antidotes for this kind of alkali, with the exception of the sodium carbonate, and adequate artificial drainage is the only practical means of reclaiming the land and providing against further disaster. The possibilities of reclaiming the level tract west of Salt Lake City will be described under a subsequent head.

One interesting fact brought out in this investigation is that alfalfa appears to stand a slightly higher salt content in the Salt Lake Valley than either in the Yellowstone Valley of Montana or the Pecos Valley of New Mexico. This may be due to the longer period in which agriculture has been practiced in this locality and the gradual adaptation of the alfalfa to these alkali lands. This is a matter which requires fuller investigation by the Vegetable Physiologist.

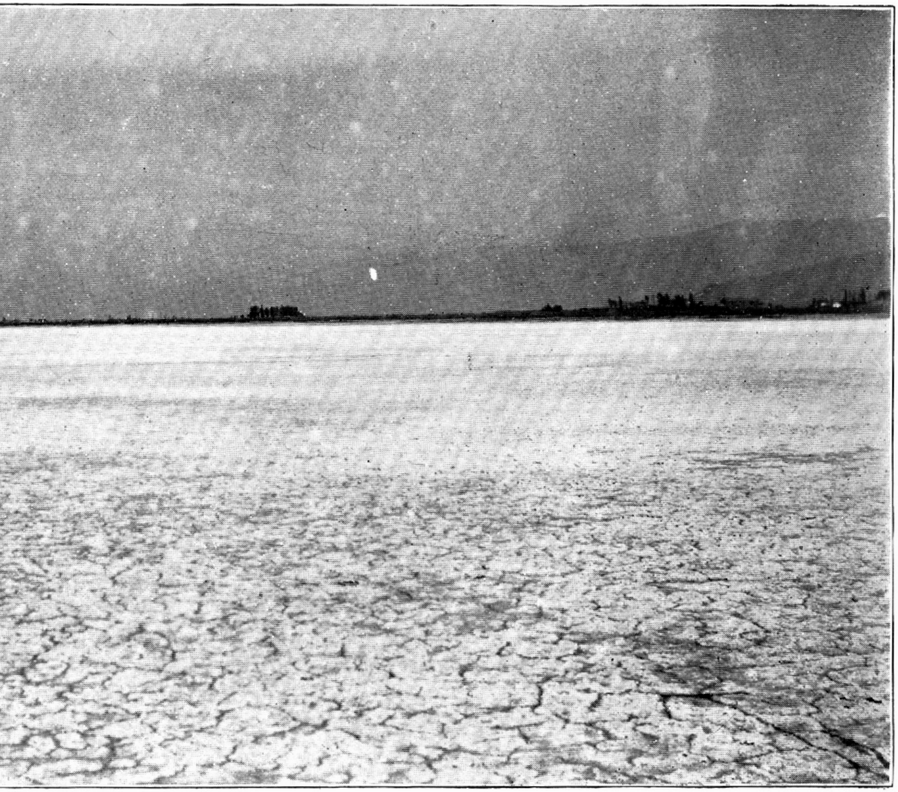
It is clearly apparent, from the investigations in the Salt Lake Valley, that our different staple crops can stand different amounts of alkali. These limits have been shown on the alkali map by different colors.

A number of factors enter into the question of the limit of endurance of plants for alkali. With the same amount of alkali plants will suffer less in the heavier soils than in the sandy. They will stand more alkali with thorough cultivation, and they will often stand a considerable amount of alkali if they are started under favorable conditions. In some districts of California sugar beets do well on soils containing a large amount of alkali. They are planted in the spring when the ground is wet either by rains or by previous irrigations, which carry the alkali into depths of the soil. When the soil dries out the alkali is brought to the surface and is left above the area of the active roots. It is a common practice in some localities to irrigate heavily just before planting in order to accomplish this very purpose. Obviously this method would not be successful when the soil to a considerable depth contains an excessive amount of salt.

Along the ridges and draws in the level west of Salt Lake City, where good drainage is secured, crops are frequently cultivated with a moderate degree of success when the land has a salt content higher than would be permissible were the drainage less complete. In a considerable percentage of this area the surface is comparatively free from alkali. Many attempts have been made to bring such land under irrigation, but the results have been disastrous after one or two years. In the upland soils of this locality the excessive accumulation of alkali, in land which was formerly free from salt, is almost invariably preceded by an accumulation of seepage water. The treatment for alkali, therefore, in soils previously free from salt, is almost always accompanied by the problem of getting rid of the seepage waters.

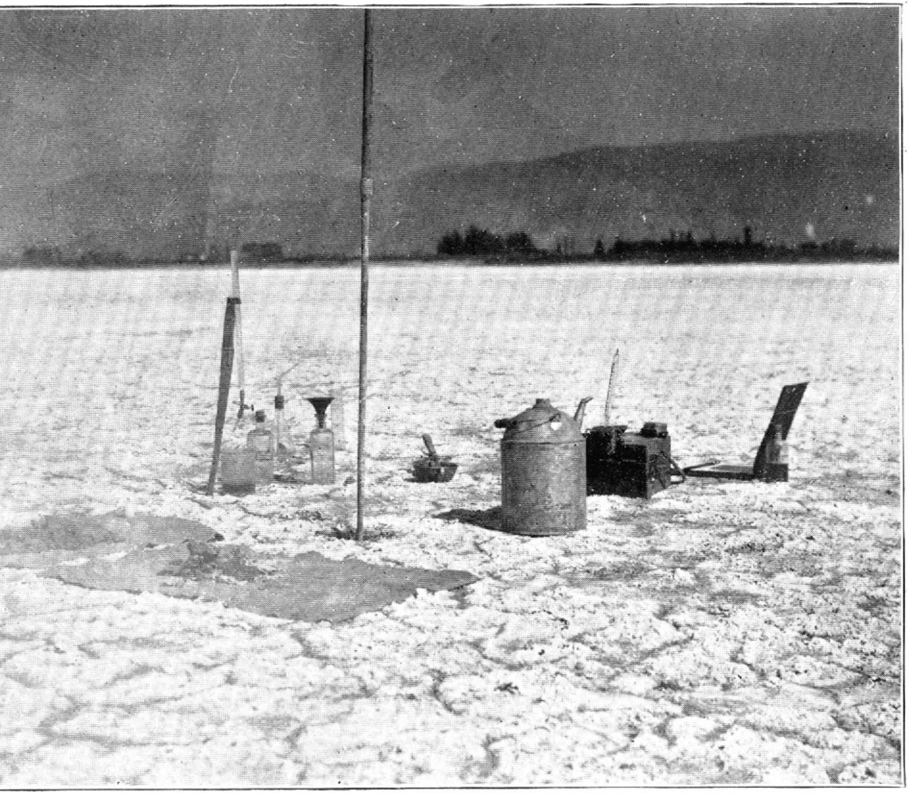
BLACK ALKALI.

The corrosive sodium carbonate is present in considerable amounts in the soils west of Salt Lake City. The best antidote for this, as Hilgard has pointed out, is the application of calcium sulphate, which, under proper conditions of drainage and aeration, converts the sodium carbonate into sodium sulphate or white alkali. On every area in which there is an excess of sodium carbonate there is also an excess of white alkali. It would be a waste of money, therefore, to apply calcium



Alkali Flat, Final Stage, with no Vegetation.

These are indeed barren.



MINATION ON RIGHT OF AUGER, AND FOR SODIUM CARBONATE AND CHLORID ON LEFT OF AUGER.

Small and convenient outfit for determining the soil conditions.

sulphate, as the sodium carbonate would be washed out along with the white alkali on the introduction of proper drainage and flooding.

The limit of endurance of plants for sodium carbonate is assumed to be that which Hilgard determines for the California soils, namely, 0.1 per cent. The lower limit of what may be called the danger line has been placed at one-half this amount.

Attention is called to the very large amount (over 0.25 per cent) of sodium carbonate in the soils of certain areas. The surface crusts occasionally contain as much as 10 per cent of sodium carbonate. Quite often there are large accumulations of calcium chlorid, which in one instance has amounted to about 40 per cent of the total salts present. There is also frequently an appreciable amount of strontium chlorid in the crust, and the suggestion is made that some of the deposits may be sufficiently rich in one or more of these three salts to warrant commercial development. No special attention, however, was paid to this particular feature.

UNDERDRAINAGE AND THE RECLAMATION OF WASTE LAND.

Attention has already been called to the necessity of underdrainage for protection against injury from seepage waters and alkali and for the reclamation of injured lands. Irrigated lands in the Salt Lake Valley are worth at least from $60 to $100 per acre. Lands immediately adjacent to Salt Lake City, especially if held as suburban property and if free from alkali, would be worth much more than this. There is plenty of good tile clay in the vicinity of Salt Lake City, and tile could be manufactured for the farmer at a reasonable cost. It is estimated that it would cost from $10 to $20 an acre to underdrain these lands which, under the present conditions, have a merely nominal value.

Lands in New York, Ohio, and Illinois, worth from $50 to $75 per acre, have been very extensively underdrained in order to increase their productiveness, to hasten the maturity of the crops, and to insure the crops from injury by drought. It would certainly be a reasonable proposition to protect these valuable lands and to reclaim in the same way what would be valuable land. Money so invested is in the nature of an insurance against loss of crops from seepage waters and alkali.

During the course of this investigation particular attention was given to the possibility of reclaiming the vast tract of 125 square miles between Salt Lake City and the Great Salt Lake. The levels of the railroad surveys and of the canal companies were freely consulted. At Salt Lake City the level of the Jordan River is about 20 feet above the level of the water in the Great Salt Lake. The distance across is about 14 miles. There is a slight ridge, however, running a little west of north, about a third of the way across from Salt Lake City. From the crest of this ridge to the Great Salt Lake there is a uniform fall of approximately 3 feet to the mile. This would be ample for the main

drainage canals, as the irrigating canals have only about one half this fall. Furthermore, there are many draws, already 4 to 8 feet deep, extending like fingers through this area, which with little additional work could be made to answer for a considerable part of the drainage system.

On account of the impervious nature of the Jordan clay, the great salt content, and the low elevation, it would not be advisable to attempt drainage over this class of land at the present time. Subtracting this area, estimated at 35 square miles, from the 125 square miles, the value of the remaining lands, if thoroughly drained, would be about $3,000,000. At present they have merely a nominal value.

Any large drainage system of this kind can be established more efficiently and economically by a company than by individual effort. For an enterprise of such magnitude—so nearly affecting the welfare of a large number of people—the State or county could well use its credit in assisting the undertaking. This is commonly done in similar enterprises in other localities. There seems to be little doubt of the feasibility of reclaiming this land from the engineering point of view and, with the abundant supply of water, there is still less doubt of the efficiency of the system when once introduced. The possibilities should appeal to the commercial spirit of the people and induce capital to undertake this very desirable enterprise.

ACKNOWLEDGMENT.

The authors wish to acknowledge their indebtedness to Col. C. A. Stevenson, secretary of the Utah State Irrigation Society, and to Messrs. George A. Lowe, T. J. Almy, E. E. Jerome, and others for their assistance and interest in the investigations. Also to Mr. Wilks, county surveyor, and Mr. Kelsey, city engineer, for base maps and data relating to water measurements and levels for various places in Salt Lake County. Officials of the Oregon Short Line Railroad kindly furnished transportation over all of their lines within the State. which was of material assistance.

NRCS Accessibility Statement

U. S. DEPT. OF AGRICULTURE
DIVISION OF SOILS
MILTON WHITNEY, CHIEF

ALKALI MAP
UTAH
SALT LAKE SHEET

UTAH AGRICULTURAL
EXPERIMENT STATION
LUTHER FOSTER, DIRECTOR

Surveyed by
Frank D. Gardner and
John Stewart
Conditions July–Oct. 1899.

LITH. BY A. HOEN & CO. BALTIMORE, MD.

Scale 1 in.=1 mile

Edition of 1899

U S DEPT OF AGRICULTURE
DIVISION OF SOILS
MILTON WHITNEY, CHIEF

BLACK ALKALI MAP
UTAH
SALT LAKE SHEET

UTAH AGRICULTURAL
EXPERIMENT STATION
LUTHER FOSTER, DIRECTOR

Surveyed by
Frank D. Gardner and
John Stewart
Conditions July-Oct. 1899.

LITH BY A. HOEN & CO. BALTIMORE, MD.

Scale 1 in.=1 mile

Edition of 1899

H Doc 399 56 1

U.S. DEPT OF AGRICULTURE
DIVISION OF SOILS
MILTON WHITNEY, CHIEF.

SOIL MAP
UTAH
SALT LAKE SHEET

UTAH AGRICULTURAL
EXPERIMENT STATION
LUTHER FOSTER, DIRECTOR

Surveyed by
Frank D. Gardner and
John Stewart
1899.

LITH. BY A. HOEN & CO. BALTIMORE, MD.

Scale 1 in.=1 mile

Edition of 1899.

H Doc 399 56 1

U.S. DEPT. OF AGRICULTURE
DIVISION OF SOILS
MILTON WHITNEY, CHIEF.

UNDERGROUND WATER MAP
UTAH
SALT LAKE SHEET

UTAH AGRICULTURAL
EXPERIMENT STATION
LUTHER FOSTER, DIRECTOR

LITH BY A.HOEN & CO. BALTIMORE, MD.

Surveyed by
Frank D. Gardner and
John Stewart
Conditions July-Oct. 1899.

Scale 1 in.=1 mile

Edition of 1899

H Doc 399 56 1